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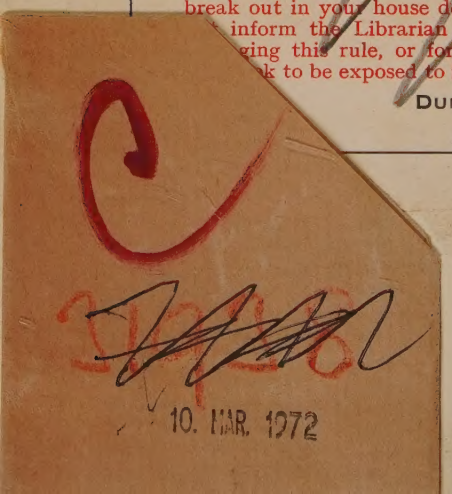

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THE LIFE-FORCE IN THE INORGANIC WORLD

By

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Author of *The Life-Force in the Plant World*

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"He that built all things"

Heb. III. 4.

FOREWORD

In writing this book, which is a humble attempt to sketch the work of the Life-Force or Creative Spirit in its building of the inorganic matter of this earth, and to obtain a glimpse, if possible, of Principles lying at the base of things, I know well that what I am attempting to paint is not standing still whilst I make a study of it, or rather, that our knowledge of it is not standing still. It is rather like the old "dissolving views" in which everything changed into something different as you tried to visualise it! The Science of Physics especially is in a state of flux and no one quite knows how it will look to-morrow. It may seem, at first sight, a rather futile thing to try to make a picture of so fleeting a show. And yet there is another way of looking at the matter.

There is no standing still in life, and no standing still in knowledge. All is in a state of continual evolution, though at one time it may be more obvious than at another. If a picture is to be attempted of the building of the Life-Force from the first point of which we can have any cognisance, we must do it at *some* moment, though our view is ceaselessly changing. The knowledge at that moment will be incomplete, but it will all hang together in its incompleteness; facts will fall into place relatively with one another, and where there are blanks, double visions, uncertainties, the mist will duly appear in the picture. We shall be dealing with

symbols and not with ultimate facts, but where in this life do we deal with ultimate facts? The symbols represent *something* though the ultimate reality may for ever escape us. If they account for "behaviour" they are probably good and useful symbols and we can use them till we get better ones which express something more of the truth.

Electrons and protons were not invented by Man. The opening of the door of the atom, which had been supposed to be an indivisible entity, by the disintegration of radium, was a revelation made by Nature herself. *Something* came forth, and Man used all his knowledge, ingenuity and patience to discover how these new particles coming forth were related to all that had already been revealed to him. He found their place. He came to realise that the new particles were not new, but built up the atom of a gas already known to him under the name of helium. He learnt, by following up this clue, how the other elements were built. He found that with slight corrections the Table of Atomic Weights, previously constructed, was extraordinarily correct. Gaps in it were filled, qualities of elements explained, combinations long known and made use of by chemists were elucidated and their meaning made clear. Fact fell into place with previously known fact, and a whole body of new knowledge was added to the old with singularly little displacement. Relatively to one another the facts were coherent, and it was obvious that a building up of knowledge of the Truth, up to a certain point, had been reached and a wide view opened.

After a while things did not go on quite so smoothly; new discoveries and difficulties of adjustment arose. Men were confronted with facts that would not fit into

the frame of the building and that upset, to some extent, what seemed to have been securely laid down. It was a case analogous to that of the " interpolated numbers " in the building of the elements, whose story I have tried to tell in simple outline in this book. There was upheaval and a disturbance of symmetry in the pattern, and there were facts which could neither be explained in their entirety by the old theories, nor by the new ; in fact it was a state of transition. Men of Science very wisely and far-sightedly in such cases held on to both old and new (apparently conflicting) theories and used them separately for the facts which could be worked by each, and watched and worked for a larger Truth which should embrace both.

We are still in that state of transition, and there are mists in any picture that is made to-day. But the main body of knowledge does answer to reality, and the entities which we know as electrons and protons do build up the elements and explain their " behaviour " under the eye of the Chemist.

A view from our present standpoint brings us into touch with reality though " through a glass, darkly." It is possible to obtain some glimpses of the Principles that underlie the building, and these are vital for us, who are the inheritors of the physical body prepared for us by these means.

As knowledge advances, those who make the effort to follow the building of the inorganic according to the view of it which can be given at the present moment, will have very little difficulty in translating the symbols used and in correcting the false steps taken, and so in following on to a clearer and deeper view.

Whatever is revealed to us, it cannot prove to be

less wonderful or impressive than what we already see : we need not fear to be disillusioned, and I am convinced from experience that the study will bring us most valuable and deeply-needed light on many pressing problems of everyday life. For this reason I have no hesitation in making this attempt to draw clearly what we seem to see, just as one might draw a picture of the natural landscape, quite undeterred by the knowledge that what our eyes show us is but a symbol of the Truth.

One effect of this line of thought is to increase—to Infinity—the value and the meaning of every so-called " fact." We know that it is only a sign or symbol of something so infinitely wider than appears ; we learn to estimate the things about us and our own actions and reactions with regard to them in a new, and even a solemn light, for the least of them may be something far-reaching and effective in the economy of things, as these unknown ultra-microscopic particles which we call protons and electrons are in the building of the Universe. Looked at in this way it seems as if the Principles of the building must be indeed vital to us and worth seeking with all our powers of mind and soul.

In *The Life of Moses*, by Edmond Fleg, I find this impressive and illuminating passage, with which I will conclude. The point at which it opens is when God has given the " Torah " (the law) to the world, and He allows Moses a vision of one who should live and teach this same Torah in the distant future. Moses exclaims : " Lord, how is this thing possible ? I do not recognise the Torah Thou gavest me. Is this new Torah Thy Torah ? " And God answered him : " There are fifty gateways of understanding : I have opened for thee

forty-nine, but the last is closed, for no man, even be he Moses, can know everything. The Torah thou understandest hath a thousand senses which thou understandest not, and which others in the course of the ages will come to know : for in each century it will speak the language of that century ; but what each century will find, is already there, and each new Torah will still be My Torah."

SYNOPSIS OF CONTENTS

CHAPTER I.—"*The Alchemists and their thoughts on the constitution of Matter.*"

Premonitions of ancient alchemists as to the possibility of transmutation of elements. Foreshadowings in their semi-mystical writings of the fundamental unity of all matter: of disintegration of existing elements as a means of transmutation: and of the energy resulting, which they called the "Elixir of Life." Their discovery, at a time when matter was supposed to be solid and immutable, of the locked door of a storehouse of energy in Nature which should one day be opened.

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THE LIFE-FORCE IN THE INORGANIC WORLD

CHAPTER I

THE ALCHEMISTS AND THEIR THOUGHTS ON THE CONSTITUTION OF MATTER

Synopsis of Contents: Premonitions of ancient alchemists as to the possibility of transmutation of elements. Foreshadowings in their semi-mystical writings of the fundamental unity of all matter: of disintegration of existing elements as a means of transmutation: and of the energy resulting, which they called the Elixir of Life. Their discovery, at a time when matter was supposed to be solid and immutable, of the locked door of a storehouse of energy in Nature which should one day be opened.

FROM very early times in the history of civilised man, we find him to have been the subject of occasional rather unaccountable premonitions of truths which really belonged to a far future state of knowledge. Sometimes it seems as if the mind which was thus inspired and uttered the half-veiled truth, was entirely ignorant of its true meaning. At other times there is a glimmering of understanding, and occasionally it seems as if a secret not yet revealed to the world, were actually known but purposely veiled.

The story of the old alchemists is full of such happenings. We can hardly take up and study any of their strange, and at first sight absurd and fantastical writings, without being startled by thoughts and

phrases which to a mind equipped with the present knowledge of physics, have a most suggestive ring. Indeed we might go much further and say that they appear in places to be speaking in guarded language and by means of metaphor of things which are now deeply occupying our minds, and still—in some cases at least—just beyond our clear sight.

In a curious book by Mary Anne South (afterwards Mrs. Atwood), published in 1850 under the title *A Suggestive Inquiry into the Hermetic Mystery*,[1] certain statements are made concerning the " First Matter of Alchemy " which to modern ears will mean something more definite than they probably did to the writer.

This " first matter," which presumably means that out of which all that exists took its rise, is affirmed to be : (1) " the homogeneity of the radical substance of things " (that is the one essence out of which all sprang), (2) " a fluid or vitalising principle invisibly permeating all things " (one thinks of the creative act of the Life-Force vitalising all), (3) " a distinct substance universally diffused " (here she seems to come from the principle of Life to the first beginning of its creation, that unknown universal matrix, by some still called the æther, out of which we have reason to believe all that we call " matter " must arise), (4) " the simple generated substance of life and light, immanifestly flowing throughout nature " (the same as the above, generated by the Life-Force, invisible and " immanifest " to the senses, but filling all with its presence), and lastly (5) " a pure ethereality which can be separated by artificial means."

[1] From this book large quotations are made by A. E. Waite in his *Secret Tradition of Alchemy*, though he is not much in sympathy with her vague and confused, yet often pretentious language.

This last sentence is more difficult of interpretation, but I gather that she intends to imply that this " first matter " which she is describing, which lies at the root of all things, can be arrived at by the breaking down of ordinary matter, and this she maintains can be done by artificial means.

If so, she was looking far beyond *us* and our powers over the atoms composing the elements ! Yet it is precisely *this* at which the old alchemists aimed, and this was the possibility in which they believed. In their strange mystic way they looked on gold as the perfect metal to which all baser metals were straining. Apparently they thought of Nature as always striving to produce this perfect product, and of all baser metals as imperfect matter which the alchemist might help towards its perfection.

The principle on which they acted seems to have been mainly that of disintegration. All the material work which they did towards the transmutation of metals was evidently with the hope and intention of reducing the base metal to that " ethereality " from which it took its rise.

Thus Mr. Pattison Muir[1] writes : " If he who was about to attempt the transmutation inquired how " . . . he was to proceed, " he would be told to ' travel along the road which was followed by the great Architect of the Universe in the creation of the world.' "

This, one presumes, could not be begun till the metal was reduced to the condition of " First Matter," and so, when he asked for further details, he was given a list of strange processes by which the substance was to be reduced. It must " first be mortified, then dissolved,

[1] *The Story of Alchemy*, by M. M. Pattison Muir.

then conjoined, then putrefied, then congealed, then cibated, then sublimed and fermented and finally exalted."

Exactly what was intended by all these directions I doubt if the workers knew, but I think the alchemists realised that by no human means known to them could the elements be reduced and built up again into the perfect metal, yet still they believed that it might be done if they could only get *behind the material veil*. Consequently they warned the seeker " that in all the operations he must use not things which he could touch, handle and weigh, but the *virtues*, the *lives*, the *souls* of such things."

It all sounds like a fairy tale in which the Prince is commanded to do totally impossible things in order to obtain his heart's desire ! But through it all the principle is perfectly plain that from one Essence all substance is made, and that transmutation is possible if we can find the mechanism by which all is built up and can learn the art of pulling down and building up. Surely, in those ancient times when matter was regarded as a solid mass, each manifestation definitely created in its entirety as it stood, it was a wonderful thing that men should have got this view of the oneness of all things and the possibility of disintegration and re-integration of existing matter !

The next point in alchemistic lore which strongly attracts our attention is the legend of the philosophers' stone—a mystical image which begins in early days as a semi-magical and elusive object which should enable men to transmute metals and to find the elixir of life (their two dearest and most ardent aspirations), but in later times seems to have risen to a higher

spiritual concept, and to stand in some relation to that "Stone which the builders refused."

A. E. Waite in *The Secret Tradition of Alchemy* expresses the view that, up to the end of the sixteenth century the true aim of the alchemists was the physical transmutation of metals; from this date onwards he notes a change, and the work aimed at takes on a spiritual meaning and concerns the Soul of Man, and the transmutation of the baser metals, which seems to be still believed in, does but symbolise the transfiguration of souls.

Professor Soddy in his lectures on Radio-activity, refers to the philosophers' stone which could, it was supposed, transmute metals and lead men to the elixir of life. Energy, he says, is the life of the Universe, and transmutation is the key to the unloosing of energy locked up in matter. Is this association of ideas merely a coincidence? He takes it for more than this; and the juxtaposition of transmutation and the elixir of life, even in those early ages of alchemy, is certainly striking.

But the Stone—the means whereby the unlocking was to be accomplished—is quite misty and nebulous. Like so much else in the mind of the ancient alchemist, it seemed like a vision without words, whereof even the form changed incessantly, so that when one writer had made an effort to describe it, or had given it certain characteristics, another would blow away the thin film of the figure he had called up and would try to materialise a spirit of his own. Even in later days, when the Stone had become more definitely a symbol of a spiritual truth, immutable as a rock may be supposed to be, the language in which it is described is paradoxical and difficult to unravel.

In the following passage from Jacob Boehm's *Threefold Life of Man* it seems to come out into the open, and one recognises it as a definite scriptural symbol: "It is accounted the meanest of all stones," he writes, "in the Adamical eyes, and is trodden underfoot, for it affordeth no lustre to the sight. If a man light upon it he casteth it away as an unprofitable thing: none inquire for it, though it be so very much sought for in this world. There is none on earth but desireth it. All the great ones and the wise seek it: indeed they find one and think it is the right, but they miss it. They ascribe power and virtue to it and think they have it and will keep it, but it is not that: it needeth no virtue to be ascribed to it."

The false stone which they mistakenly cherish is: "glistering with a pleasant outside or sound," but it belongs to "the wall of the great building of this world in which the seven seals accomplish their wonders and under which the seven spirits of the anger of God pour forth their vials of wrath."

In all this it is evident that what the man of the world sought for in this stone was *power*. They desired to have the key which should unlock for them the secrets of Nature and unloose the energy which meant life and all that makes life beautiful and enjoyable. And all through the annals of alchemy, from the more materialistic beginning to the more mystical development, the same idea rings clearly—that only by some entering-in behind the veil of things—by some secret union with the Life that has brought all into being, can that object be attained.

In the earlier times, as we have seen, they thought to reach it by strange processes aiming at the dis-

integration of matter, but always by means of some grasp of that which lay behind the matter to be disintegrated; and this, I think, is the meaning of the Stone which was to confer that mystic power. I fancy that from the first it was a symbol of That which brought all into being and that the idea became more definite and less material as time went on.

As yet we have no more certain knowledge than they had as to the means of unlocking the storehouse of Nature. But how wonderful that they discovered the storehouse, ascertained that it was locked, and looked with hope and faith to the unlocking of it some day by the power of the mystical Stone!

Let us now try to see how our present knowledge answers to these faint foreshadowings, and what the locked door reveals when—to our stupefaction—Nature herself unlocks it for her own purposes, yet without giving us the key!

CHAPTER II

THE DOOR BEGINS TO OPEN

Synopsis: The Atomic view of the Universe. Held by ancient Greeks and revived by John Dalton. Atoms supposed to be changeless, immutable—the fundamental " bricks " of the Universe. Discovery of Radio-activity : the opening of the " changeless " atoms and transmutation of the elements. The door opened by Nature. State of knowledge at this stage and manner of the discovery.

Up to almost the end of last century all delving down to the foundation of things stopped with the *atom.*

The " Atomic Theory " of the Universe was by no means a new one. It had been held by the ancient Greeks (another example perhaps of " foresight ") but had been dropped out of mind for many centuries and was revived in comparatively recent times by John Dalton (1807)[1], who appears to have forgotten that it had ever been held before. It was, however, by the end of the nineteenth century, no longer a theory, but a proved fact.

Over eighty distinct elements were known, and it was found that the atoms which composed each separate element were precisely similar. So many elements, and so many distinct kinds of atoms ! So many kinds of bricks whereof all the Universe was built ! It seemed amazing ; and having reached bottom apparently, some wonder was felt at the fact of a certain fixed number of sorts of bricks (I believe it was 88)

[1] *A New System of Chemical Philosophy.* John Dalton.

being found to constitute the entire inventory for the building, not merely of this world, but of the whole Universe. For it was realised, and proved by the spectroscope, that all the elements—iron, oxygen, hydrogen, carbon and so on—which exist in the sun and stars, have precisely the same constitution and similar atoms to those of these elements on our earth.

In 1873 James Clerk Maxwell in an important and eloquent speech declared that it was impossible that evolution should account for these groups of precisely similar atoms, for evolution, he said, presupposes change and these atoms were changeless—incapable of growth or decay—and bore all the signs of heavenly manufacture ; at all events they were not made by any of the processes that we call natural. In short if men were no longer unanimous in their belief in a Nature created in set pieces, they still inclined to believe in a Nature built of bricks, moulded once for all and set in an eternal shape by the hands of the Creator. And so the first processes of creation were the formation of dead matter, and the Life-Force was to build with this !

And then in 1895, Professor Röntgen discovered the X-rays, and in 1896 Henri Becquerel made the first discovery of radio-activity, and all the scientific world was startled ; and thought had to undergo a revolution.

For behold, the dead " bricks " had come alive, the " changeless " atoms had opened and were sending forth particles from their unknown interior, and changing as they did so into other elements—many of them hitherto unknown ; and nothing man could do to the radio-active element could stop this strange, ceaseless change which went on without apparent

diminishing of the element in question, even as the Burning Bush of old burned and was not consumed. "Nothing can go of itself," the scientists had constantly affirmed (and with reason), yet here were elements giving forth energy in an apparently causeless manner and without apparent diminution. It was certainly very subversive of all received ideas.

The door was open just so far as Nature chose to open it, and no man could shut it. On the other hand no man could open it further or obtain one grain more of the store of energy that Nature chose to dole out through the small crack.

Fresh discovery and thought seem to have come in then in a rush. Much work had been done on the atom before this, and very much had been learned about it which now was elucidated and enlarged by the new discoveries.

It had been definitely established that the atoms composing all the known elements were peculiar to each element, and those composing any one element were precisely alike. In fact the definition of an element is: a substance which, when resolved by the chemist into its constituent atoms, is found to have only one kind of atom—that belonging to its own nature. Oxygen, carbon and hydrogen are such. If two kinds of atoms result, as is the case with water, for example, then the substance is a compound of two elements; if three kinds of atoms are found, it is a compound of three elements; and so on.

The smallest part of a compound substance which can exist *as that substance* without being separated into the different kinds of atoms composing it, is called a *Molecule*. Thus a molecule of water contains 2 atoms

of hydrogen and 1 atom of oxygen. As long as it binds these together and remains a molecule it is still water.

All this was common knowledge to the chemists of those days. Indeed they had gone much further. The 80 or 90 elements known to them were found to have different weights; no two were the same, and they could be arranged in regular order beginning with the lightest and going on to the heaviest. In many cases these weights could not be ascertained by the ordinary methods. A gas, for instance, would seem to vary enormously in weight according to temperature, pressure, etc. This would really mean that a larger or fewer number of atoms were contained within the receptacle holding the gas; so obviously the only way to obtain accurate results was to find the *relative* weights of the *atoms* of different substances. By methods involving both ingenuity and patience, this was done, and the elements were arranged in order according to their relative weights, from hydrogen, the lightest, up to uranium, the heaviest known element.[1]

When this was done it gradually became clear that some elements were chemically related to others, that they had the same properties and belonged to the same group.[2] Take, for instance, lithia, soda, and potash. We all know that they are alkalies and have many of the same properties. Such groups are to be traced throughout the list of elements; but when all the elements were arranged in an orderly Table according to their respective weights, it was soon noticed that

[1] This great work was completed in 1858 by Cannizzaro.

[2] The name of A. E. B. de Chancourtois must be associated with this portion of the work on the relations of the atoms (1862).

the members of such groups occurred at certain definite periods throughout the list. Thus with the three mentioned above, their numbers being 3, 11, and 19 respectively, they occurred at intervals of 8; and this was the period for the members of groups in the earlier part of the Table. Later on the period became not 8, but 18, and further on still it was 32. (See Table of Atomic Numbers, p. 40.)

There were other complications which I will not go into now, as the point for the moment is the fact that the related elements recurred at *fixed intervals* in the list of elements.

This must have seemed inexplicable, because as long as atoms were thought of as indivisible particles of matter having no known structure, it was more than strange that there should be a perfectly definite and settled order of recurrence between similar substances when the elements were arranged according to their atomic weight. However, if the atoms were to be regarded as manufactured articles turned out by the million in so many assortments for the building of the Universe, perhaps, with so much taken for granted, it would not be hard to go further and to say: "bricks nos. 3, 11 and 19 are used for building elements having such and such similar chemical affinities and properties; bricks nos. 4, 12 and 20, ditto," and so on without further inquiry, but merely as stating a proved fact.

It was into a milieu of this kind that the discovery of radio-activity came like a bomb.

Of course experiments had been going on ceaselessly in pursuance of the furtherance of knowledge. Physicists and chemists might believe that in the atom we had touched bottom as regards the origin of things,

indeed Clerk Maxwell had definitely said as much. But there was much on all sides to investigate, and a steady endeavour was kept up to push back the fringes of the darkness that shrouded knowledge.

In the course of experiments Professor Röntgen had discovered the X-rays which had power to pass through opaque objects and affect the photographic plate. It had occurred to someone that possibly phosphorescent objects might emit similar rays, and M. Henri Becquerel by great good fortune chose uranium as the phosphorescent substance for his experiments, and was led to the discovery that uranium—not by virtue of its phosphorescence, but by a "radio-activity" peculiar to it and not possessed by other phosphorescent objects—did emit rays penetrating opaque objects even in the dark. This was actually the first hint of the existence of radio-active substances, and startling as it was, it was some time before all that the discovery meant could be grasped.

Very soon the discoverers became aware that they were up against a new thing in their knowledge of Nature. At first sight the apparently self-evolved energy of the radio-active substances, without either visible cause or diminution, was really disconcerting, and indeed appeared to be opposed to all the established principles of matter and energy. But in his book, *The Interpretation of Radium* (1912), Professor Frederick Soddy points out that this opposition was only in appearance, and that the new knowledge had in fact only "given to the old laws and theories a fuller and truer significance than they had before." "It is wonderful," he remarks, "how accommodating a true theory is to new truth, apparently of a diametrically

opposite character, and this not in any sense of mere ingenuity of explanation, but in a manner that arrests the investigator and is the sign that he is on safe ground."

How true were these words we shall see as we study the meaning of radio-activity more closely, and watch its effect upon all previous knowledge and theory. The idea is peculiarly encouraging to us who are trying to study the building up of matter at a time when confessedly the whole subject, as understood by present-day physicists, is in a transition state, and truths which once seemed as firm as the foundations of the earth, are felt to be insecure, and may need to be seen shortly in a totally different light. If so, let us be sure it will only be a clearer one. When Professor Soddy wrote this book in 1912 things were shaking somewhat as they are doing to-day. The conclusions which had already been reached appeared most startling and revolutionary to all received ideas, and it was felt that the ultimate destiny of Man might be strangely affected in time to come. For it now appeared that in the elements a vast store of energy was imprisoned, which at present Man had no means of freeing, but which in the radio-active substances revealed itself in spontaneous ebullitions which no man could hasten or hold back.

Uranium, though the first to be discovered of the radio-active substances, is by no means the most powerful. After its discovery Mme. Curie set herself to search for other radio-active elements, and eventually she discovered thorium. Neither this substance nor uranium was usually found pure, but they were contained in natural minerals from which they could

be separated. In a certain kind of composite mineral called pitchblende, there is often more than 50% of uranium oxide present, but in some cases it was found that pitchblende might be three or four times as radio-active as pure uranium oxide ! This, of course, proved the existence of some more powerfully radio-active element than uranium in the pitchblende. Eventually, associated with barium, minute quantities of a new radio-active substance were found in these pitchblendes and were named radium.

The quantity of radium associated with uranium in pitchblende is one part in every 3,200,000 parts of uranium. Yet this minute quantity had made itself felt as shown above.

CHAPTER III

RADIO-ACTIVITY

Synopsis of Contents: Constitution of atoms explained in the light of later knowledge. A picture of what takes place in radio-active elements. An atom of disintegrating radium supposed to be transparent and so magnified as to be visible to the naked eye. Its disruption watched. The resulting elements examined and explained. The series of transformations that result, and their meaning. A view of the radium atom before its disruption.

WHAT is it that is taking place in the radio-activity of certain substances?

To understand this we must return to the Table of Elements arranged according to their atomic weight,[1] and in the light of knowledge which has grown since the discovery of radio-activity, we must go beneath the surface of the atoms of which the elements are composed, and try to get a picture of their constitution. We now come to see the atoms of the different elements no longer as solid "bricks" but humming with life and activity—planetary systems in miniature, as they have been described, with a store of untold energy locked within those frail walls, and a wonderful order, rhythm and co-ordination peculiar to the atoms of each individual element.

Beginning with the simplest—that called hydrogen—and moving in steady progression to the most complex and the heaviest element known, uranium, we shall

[1] For this Table credit is usually given to Mendeléeff (1869–71).

see the plot gradually thicken, and the system of the heavier atoms will exhibit a dance of life of which the pattern is too complicated for even the brain of the trained mathematician to follow as yet.

Let us suppose the atoms to be transparent as glass, and let us try to get a glimpse of what is passing within. Every atom seems to be composed of a nucleus or central mass, answering, we will say, to the sun, and of one or more " planets," circling round it in varying orbits. Tiny as the atom itself may be, the enclosed bodies are so much smaller that there is ample room for the gyrations of even the great number of " planets " which the heavier elements contain.

What are these bodies, and why do they thus behave?

The central nucleus consists, at least in part, of charges of positive electricity associated with matter, whilst the revolving planets are pure charges of negative electricity dissociated from matter and bound in their course by the attraction of the positive nucleus. In the hydrogen atom, which is the simplest of all, there is just one unit of positive electricity, as a nucleus, and one unit of negative electricity circling around it and held by its compelling attraction.

At one time it was thought that the nuclei of all atoms would prove to be built up of hydrogen nuclei[1] or single units of positive electricity called " protons," and this would have seemed a very simple arrange-

[1] This was Prout's hypothesis (1815), which was based upon his discovery that when the atomic weights of elements were related to that of hydrogen, if hydrogen were expressed as 1, the other elements had very nearly whole numbers as relative weights. This theory seemed to point to hydrogen as that " First Matter " of the alchemists, out of which by some series of condensation all elements primordially took their rise.

ment and easily to be understood! But Nature is apt not to be so simple as she appears, and the plan did not work.

The atom of the next element, "helium," has two planets circling round its nucleus, and as we go up the Table of Elements arranged according to their atomic weight, we shall find that each element has one more free electron, or planet, circling round the nucleus of its atom, till we reach the 92nd and last element, uranium, which has 92.

But you must not suppose that it is the electrons which determine the weight, or that this proceeds evenly from 1 to 92. This is by no means the case. It is the protons which weigh—the weight of the electrons being negligible—and the nucleus containing them is a complicated affair, so that the weight of an atom of uranium compared with that of an atom of hydrogen (for remember, this table of weights is *relative*, not a list of actual grammes or grains), is, approximately, 238 as compared with 1. This, of course, needs explanation, for you would naturally think that as the electrons increase by one with each new element, so must the protons do. But this would be that nice, simple arrangement of which we spoke a moment since—which did not work!

Returning to No. 2 in the Table—that is helium—we find there are two electrons but the atomic weight is 4, which would mean that there must be four protons in the nucleus, because each proton is, of course, equivalent in weight to the hydrogen proton. Yet there are only two circling electrons, and this would appear to leave two of the four protons "unsatisfied" and crying out for satellites to neutralise them. In fact this would

mean that the atom of helium would carry two charges of positive electricity, which is not the case in helium in its ordinary condition.

The explanation of the problem appears to be as follows: the helium nucleus is composed of four protons, two of which are "satisfied" or neutralised by two electrons *incorporated with these protons in the nucleus;* two free electrons circle round as satellites and neutralise the two remaining protons.

It is very important to get a clear grasp of the constitution of the helium nucleus, because it plays a most important part in the building of all matter; moreover, if we understand the principle of grouping of protons and electrons in this simple nucleus, it will be easier to follow it in the nuclei of the heavier and more complicated atoms.

To simplify our mental picture let us think of the protons which are neutralised by electrons *within the nucleus* as "married protons" living with their husbands, and of those neutralised by circling electrons outside the nucleus (but of course within the atom) as unmarried ones with lovers. The helium atom consists of two married protons with their husbands, and two single protons, all living together in the compressed area of the nucleus, and two electrons circling round. There are six little particles of electricity forming the nucleus, of which four are neutralised by each other. The two remaining ones are calling to the two revolving electrons outside and receiving their answer. Thus the helium nucleus (*not the atom as a whole*) has a positive charge of two, that is it calls for two units of negative electricity, and it is satisfied by the two planetary electrons.

Number 3 in the Table of Elements has three free electrons, and the nucleus has three single protons calling to these three "lovers." The positive charge of the nucleus is 3. Number 4 has four free electrons and four single protons and the positive charge is 4. And so it goes on through the whole list of elements till we reach uranium with 92 free electrons and a charge of 92. The relative weight of uranium compared with hydrogen is 238 to 1. There will, therefore, be 238 protons of which 146 are "married" and 92 are "single" and calling to the 92 free electrons which dance around that closely packed nucleus!

We are now in a position to get a glimpse of what happens in radio-active elements. Of these radium is the best known to the general world, though, as we have seen, it was not the first to be discovered. The rays which it ceaselessly gives forth are totally uninfluenced by anything that man can do. Neither heat nor cold stops them, and they are indifferent to any treatment that can be devised.

Sir Isaac Newton when trying to solve the problem of the nature of light, suggested that it consisted of a host of tiny incandescent particles given off by the radiant object emitting the light. He appears to have been nearer the truth than anyone guessed for very many years after his time; for though the next theory which grew up and seemed to fit the facts, represented the emission of light to be in the form of waves shaped like a hemisphere and transmitted to us one after another in regular sequence, yet it presently was found that this did not explain or agree with all the facts which came to be known; and side by side with this wave theory which could not be entirely given up, as

it explained certain facts which were otherwise inexplicable, a new view was accepted by which light was conceived to be emitted in what might almost be described in Sir Isaac Newton's phrase, as tiny incandescent particles. However, they must not be thought of as solid atoms, which this seems to imply, but rather as separate emissions of tiny quantities of "action," that is of energy persisting for a given time.

These two theories of light, the continuous-wave theory and the separate-atoms-of-action theory, cannot be reconciled at present, and physicists have to hold on to *both*, being sure that the underlying truth embraces both, and seeing that each explains certain facts and must be used in work on these different facts.

Sir Isaac Newton's suggestion as to the nature of ordinary light was, however, so prophetic of the real truth about radio-active substances and the rays which they emit, that one seems again to catch a glimpse of that strange "foresight" which from time to time inspires the human mind and reveals facts for which the state of knowledge is not yet prepared. For it is found that the greater part of the rays given forth by radium and other radio-active substances, are almost precisely what Sir Isaac Newton imagined the rays of ordinary sunlight to be.

I say "the greater part" because the rays are found to be of three kinds, called the "α" (alpha) rays, the "β" (beta) rays and the "γ" (gamma) rays, and of these the first two consist of minute particles shot forth from the atom, whilst the gamma rays are really light waves or "atoms of action." It is the first two classes which interest us mainly, and we will concentrate on the α-rays and see what happens when they are shot

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forth. The other two sets of rays really belong to a later stage of the proceeding, as I shall be able to explain further on.

In order to see this process in a clear and interesting way, it is a great help to have a vivid mental picture. Physicists warn us of the danger of such pictures which tend to make solid concrete things of what are really still very illusive ideas and may not have at all the clear-cut form which we give them. But even in abstract ideas we have to form some sort of pictorial representation in our mind, and we know that we are only using this as a way of dealing with a Truth which lies underneath our picture. If we think of protons and electrons in this way, we shall not be startled if the physicists tell us later that these are not composed of " matter " at all (as we understand it) and are, to use the phrase of Mary Anne South : " a pure ethereality," or, as the ancient alchemists put it : " the virtues, the lives, the souls of such things."

With these safeguarding remarks, let us try to see a picture of what is happening in a radio-active substance.

Imagine that all its atoms are transparent and that they are enlarged so much as to be visible to the naked eye. The substance we are looking at is radium, and in the packed nucleus of its atoms we shall see assembled a community of 138 " married " protons with their partner electrons, and 88 single protons.

Do not imagine that they are living calmly and in peace in this minute and cramped habitation. Every proton has naturally a repulsive force for every other proton, and normally every electron would repel every other electron, though certain magnetic forces may modify this. Every proton, married or single, attracts

to some extent every electron within the nucleus, and these in their turn may be supposed to have attraction not merely for their legitimate partners, but for the single protons dwelling in the nucleus. Besides this there is the strong active call of the 88 free protons for the 88 free electrons circling round the fortress, and the answer of these humming back to satisfy them. The picture, as I see it, is like that of a hive of bees in fierce unrest, just before they swarm, and one feels that sooner or later something is bound to happen!

Presently as we look more closely and carefully into the "small, fierce world," as Bertrand Russell describes it, we notice that the community is mainly grouped in little bands of six, four protons and two electrons (that is two married couples and two single protons), and these six appear to be welded together with extraordinary firmness, so that they act and move as one, and nothing can by any means succeed in breaking them up. Two outer electrons, of course, belong to the two free protons in this alliance, but these latter appear to be satisfied to wave and call to their lovers and never dream of breaking away from their friends, the two married couples.

Quite suddenly, and without any special apparent cause, the "happening" which we have been anticipating occurs, and one of the nuclei disrupts or bursts, shooting forth with intense velocity one of the closely banded groups of six. This missile rushes forth into the world beyond the atom whose nucleus it helped to form, leaving behind it the two electrons whose mates it carries within it, crying for their lovers.

The particle shot forth out of the nucleus of a radium atom, having lost its two attendant electrons, is now

calling for others to take their place and thus has a double positive charge of electricity. Ordinary matter does not stop these particles till their energy is exhausted (they have their natural " range " like rifle bullets) and as they go they call vehemently for electrons to supply the places of the missing ones, and soon two of these are torn from the surrounding matter and attracted to them, satisfying the two desolate protons.

Now before we return to the atom which they have left behind them, let us for a moment recall our study of the helium nucleus which we shall find exactly answers to the description of the α-particles shot forth from the nucleus of radium when disrupting. Indeed they are one and the same thing, the α-particle being in fact a helium nucleus shot forth from the immensely more complicated nucleus of the radium atom. It is positively charged at first, through the loss of the two electrons belonging to it, but on acquiring others, it becomes an ordinary helium atom.

Here is a most remarkable and intensely interesting thing ! here is an atom of a very heavy, complex element suddenly bursting without apparent cause, and giving out from its nucleus a pure atom of another well-known very simple element. Yet when . the element, radium, is examined by the aid of the spectroscope, and its light analysed, it gives no hint of helium in its lines !

I need not interrupt our study of the disruption of radium atoms to go into an explanation of the way in which the spectroscope is used to diagnose the presence of a particular element by its " spectrum," but it is a sure method and is the foundation of most of our knowledge of elements as existing in worlds beyond this

one. Certain definite, well-known lines in the spectrum represent each element and can easily be recognised.

There is no helium in the spectrum of radium, yet the radium nucleus emits particles which prove to be pure helium nuclei, and when they have acquired their two new electrons, are helium atoms like any other, and their spectrum shows the characteristic lines of helium!

Here is indeed a wonder, and here we have touched the fringe of the chemistry of the great Builder who welded together these living "bricks" before Man was, and has apparently used them intact in building elements which are as distinct from these component parts as radium is from helium, yet wherein the "bricks" are still whole and separable, though not by Man! Does not the dream of the old alchemists seem to be coming true? and is there not here a glimpse of the work of Nature in breaking down and transmuting that which she has built in secret? That last secret she still keeps, for no man yet has seen the Life-Force in its work of *building up*. This is yet to come, perhaps! Meanwhile here is veritably going on the work of transmutation of elements, as we shall better understand shortly.

Let us return for a while to the piece of radium from which the α-particles are shooting.

Only a very small proportion of its atoms are disrupting at the same time, but so vast is the number of minute atoms which go to make up a piece of radium weighing one grain that it is calculated that about ten thousand million α-particles are expelled from it in every second of time. Yet some 1580 years must elapse before half of the atoms in that grain of radium

have disrupted and shot forth each an α-particle ; and during our lifetime and far beyond it, no appreciable change will be seen. This gives us some conception of the " infinitely little " into which we are gazing.

The question which now interests us is that of the state of the atoms which have disrupted and shot their bolt. They have parted with four protons and two electrons from their nucleus, and the two attendant electrons which belonged to the single protons have, as a general rule, gone too, for they are usually torn out from the atom as the α-particle containing their mates rushes forth. What is the result in the atom as a whole ?

The place of radium in the Table of Elements was No. 88, which meant that it had 88 single protons in its nucleus calling to 88 lovers outside, that is its nucleus had a positive electrical charge of 88. The relative weight of radium, compared with hydrogen (taken as 1), was 226. Now all this is changed. There are only 86 protons calling from the nucleus, so the nuclear charge is 86 ; and the loss of the four protons (married and single) reduces the weight to 222. What does this mean ? It means that the disrupted atom is no longer radium, but a *different element*, with a different place in the Table of Elements, a different nuclear charge and a different weight.

Its number is 86 and an empty place awaits it in the Table of Elements, for up to the moment when this disintegration of radium was first watched, No. 86 has had a blank against it. There are still a very few empty places waiting for their elements to be discovered, but one by one the gaps in this regular Table have been filled —a wonderful verification of the truth of the work done

by the chemists who found the atomic weights and set the elements in order.

Here at last we are actually witnessing the transmutation of one element into another, which was the dream of the old alchemists. Only it is performed by Nature and not by Man.

And what is this new element which results ?

Although out of 138 married protons with their partner electrons and 88 single protons which crowded the nucleus of each radium atom only four protons (two married and two single) and two electrons, have gone, yet the whole nature of the disrupted atoms has changed and we see now a radio-active *gas* taking the place of the " solid " radium. The α-particle or helium nucleus which has been shot forth, is also now the atom of a gas, for helium, like oxygen and hydrogen, exists normally in the state of gas. So the disrupting atoms of radium appear to be dissipating into two kinds of gas, helium and the new element called niton or radium emanation.

This gas or emanation may be caught in a sealed flask containing the radium which emits it, and it is seen to be radio-active, that is to say, it also is giving forth α-particles, and many more in relation to its volume than radium does ; so it is disintegrating much faster, and, as in the case of radium, when an α-particle shoots forth from the nucleus of its atom a new condition of the whole atom again arises, and it is once again a different element !

But the excitement of " swarming " seems to have caught on, and in a few days the radium emanation has all disintegrated (though of course more is being formed all the time) and meanwhile quite a number of

new changes have taken place, the atoms of the new elements disrupting almost as rapidly as they are formed, and giving forth not only α-particles, but also β-particles which are simply electrons, and γ-rays (gamma rays) which are waves like those of light. These are the three kinds of rays which are said to come from radium, but of which the last two come from its *products*.

The series of changes goes on, sometimes faster, sometimes more slowly, and in the end it comes to rest as a form of *lead*, which, not being radio-active or giving forth its particles by disruption, remains apparently changeless and stable. In the long course of disintegration, radium, with a weight of 226 has gone back to lead with a weight of about 20 points lower, the remainder of the original substance having escaped as helium with its atomic weight of 4.

The lead which is formed in this way by the disintegration of radium is slightly different in weight from ordinary lead, and this brings me to the mention of so-called "isotopes," that is elements having the same atomic number and similar chemical properties, but different weights (like the different sorts of lead), and it must be understood that some of these products of the disintegration of radium and of other radio-active substances are isotopes of other elements and share their number. Radium itself has mesothorium for an isotope and these two are identical in their chemical properties and can be used for the same purposes, but they differ in the rate at which they are disintegrating, the latter substance wearing itself out infinitely more quickly than radium. Isotopes always have the same *chemical* properties because they have the same number of electrons in their last shell or group round the nucleus

and it is these which decide the chemical nature. They may differ slightly in some physical qualities such as density and rate of diffusion or of disintegration.

If you look at the Table of Elements on page 40 you will see that their atomic weights in very many cases are not simple whole numbers but have some fractions following them. The reason of this is that in many cases these elements are really composed of two or even many isotopes, which cannot as a rule be separated by human agency—at all events at present. These have the same atomic number and chemical properties but differ slightly in weight. Generally the weight of each of these isotopes is a whole number, but when they are all mixed up together in varying proportions, the average weight of the whole is apt to come out with fractions. Thus potassium whose weight is 39·1 has most of its atoms with atomic weight 39 but just a few 41. Both kinds are truly potassium and have precisely the same chemical properties ; the two kinds always exist in the same proportions and together they form the element potassium with atomic weight 39·1.

In this very rapid and cursory sketch of the events which are taking place in radio-active substances, I have, of course, barely been able to give a glimpse of all that is really happening, but it may be sufficient to enable those who have had no previous knowledge of these matters to realise that the doors are slowly opening, the possibility of the transmutation of elements has become a certainty, the " dead " bricks of the Universe have come to a life of their own and are shooting forth energy. Man's horizon and his hopes are widening, and yet . . . behind all this the secret Builder keeps

his secret, for no man knows the source of that energy which is locked in those atoms of matter.

We know that our earth is ceaselessly receiving light and heat from the sun, but beyond this it is found that there is a much more penetrating radiation of energy constantly reaching us, which is invisible yet capable of passing through an immense thickness of matter. The origin of this radiation is unknown. Some think it comes from the disintegration of elements in far-off stars, similar to the disrupting of the atoms in radio-active substances. Those who hold this view think that the Universe which has been " built " in secret by the Life-Force, is gradually " running down " like a wound-up clock, and that all the light and heat and energy by which we live is due to the disintegration of the elements in cosmic space. Others hold the opposite view,. and believe that the energy is set free in the course of the secret building up of elements, perhaps now going on in the awful furnaces of giant stars.

This is not impossible, for in the welding of those four protons and two electrons which constitute the helium nucleus, it is known that energy (which is the equivalent of mass) must have been lost and radiated away, because the helium nucleus instead of weighing exactly four hydrogen nuclei as it should do, weighs a trifle less, for the actual relative weights of the two are hydrogen 1·008, and helium exactly 4 as you see in the atomic Table. The remainder of the mass or energy was radiated away in the closer packing of the protons and electrons in the helium nucleus. Calculations and observations have served to convince the physicists that the cosmic radiation *could* be produced by the building up of elements as well as by their breaking

down. The former process has certainly taken place in the past though no man has witnessed it ; the latter is going on in miniature before our eyes in radio-activity.

Turning once again to the disrupting nuclei of the radium atoms, and thinking of the amazing energy which has been locked up in them, we are impressed by the immense forces revealed in these ultra-microscopic particles of inanimate Nature.

Look once more into this marvellous system of the radium atom before its disruption. See the dance of the 88 electron planets round that crowded nucleus which is their sun. Each one has its own orbit, and most of them are revolving, not upon their own tracks but so as to form a sort of rosette in their ceaseless whirling around their course ; and meanwhile it is believed that under certain shocks or stimuli from without they are leaping at intervals from ring to ring, nearer or further from their sun, like sparks flashing from the centre and returning, yet each one in an order and obeying a symmetry instilled by the building Life-Force. What intricate pattern are they weaving in their mazy dance—beyond man's highest power at present to follow ?

In their midst is the nucleus, this strange, close-packed fortress of energy, ominous in its apparent stillness, full of potentiality. Something of its locked-up forces can be gathered from the velocity of the missile which it shoots forth upon its sudden disruption. The α-particle travels with a speed said to reach 20,000 miles per second. Endowed with this energy, it is a different thing indeed from the atom of helium gas into which it gradually subsides.

Imagine what we could do if we had the knowledge

to unlock that storehouse of energy for ourselves, and use the atoms of radium for our power-houses ! And it is probable that in *all* matter, and not merely in those elements which are seen to be radio-active, there are stores of untold energy locked away, though we may not ever see the door for a moment open, or the flash of an escaping spark.

CHAPTER IV

THE LIFE-FORCE BEGINS TO BUILD

Synopsis of Contents: Thoughts on the Life-Force and its work. Our own creation involved, and the principles of building consequently of immense moment to us. Conflicting views of physicists, chemists, and mathematicians respecting the nature of electrons and protons constituting the atoms of matter; yet the building of these to be watched, order and symmetry discovered, and facts explained in the process. Arrangement of the elements according to their atomic weight. Related groups in the list of elements. Constitution of the elements; their nuclei with "married" protons and electrons, and their atomic charge represented by their number in the list. Table of Atomic Numbers. Arrangement of the electrons around the nucleus. The great "Wheel of Life" and views of it from many angles. The ring-like groups of electrons, answering to the groups in the Periodic Table of Atomic Numbers. The first group complete in helium. Building of the second ring-like group or story of the edifice, complete in neon. The third story completed in argon, No. 18. Diagrams showing the chemical affinities of elements to depend upon the arrangement of the outer electrons and the "pattern" they form around the nucleus. The fourth story starts, and work on it unaccountably ceases. Strange phenomena in the new elements now being built. Professor Bohr's explanation. A work of consolidation going on within: empty circles to be filled. The "interpolated numbers." Spiral form of the Table of Elements representing the rhythm of the building. The fifth and sixth story. Another series of "interpolated numbers." The last group unfinished or broken off: its elements probably too unstable to maintain existence.

WHAT is this Life-Force which we have watched at its work of brick-making? and what is its relation to these electrons and protons which it seems to gather from nowhere, and to weld in secret laboratories by energies unknown to Man?

In whatever way we may answer this question, we

must, at the least, acknowledge that it is the same Life-Force which has brought ourselves into being. According to the now almost universally held doctrine of evolution, the body through which our spirit functions has been gradually prepared and built up for us through long ages. We cannot think of it as merely derived from animals, as that would simply be to antedate the miracle of special creation and give that honour to the animal. Besides, the same considerations which have led to the belief in the evolution of man from the animal creation, carry us back, without allowing us to pause, right to the very beginnings of life. Whether there is a break there, or whether the inorganic is but unborn life, with all the potentialities and possibilities of freedom and individuality growing within it and waiting for the hour of liberation, may still be a disputed point. "Dust thou art and unto dust shalt thou return," says the Ancient Book, and indeed we seem to derive this body which has been prepared for us, ultimately out of the very dust which goes to form the "Bricks of the Universe."

The lines of thought seem to be drawing towards the conclusion that there is no break, no moment of fresh beginning. Into the particles which we know as electrons and protons, the Life-Force or Creative Spirit appears to breathe something which holds a shadow of the life to be: something which enables the inorganic to weld itself together in amazing ways to form elements, and then the elements to call one to another through the attraction of their particles and to unite in compound substances, and so by degrees the inorganic world comes into being in preparation for the life which is already secretly stirring. And—still without fresh miraculous

creation—we see a new and higher condition arise in the prepared matter, and the breath of life, which has been immanent in the living Bricks from the first, expresses itself in clearer form, and a Birth takes place—the birth of Life as we know it, with all its potentialities and powers, still folded in the helpless naked "speck of protoplasm."

According to this view it is surely of immense moment to us to follow the building of the Life-Force from the point of its first materialisation in these inorganic particles, for it is indeed *our* beginning at which we are looking, or at the least, it is the work of the same Life-Force which was our Creator. It must have meaning for us and express principles deeply implanted in the constitution of things, and it is for us to search them out with patience and understanding, and to take them to heart in our daily life, believing in their power to elucidate many of our problems and to help us to a fuller comprehension of ourselves and our true goal.

In all our studies of electrons and protons and the way in which they are built up into atoms to form the different elements, we have to keep in mind that these particles of electricity—"negative" and "positive," so-called—are very much under the limelight at the present moment and are being studied by chemists, physicists and mathematicians with unceasing ardour.

Views respecting the nature of the former are changing so fast that to get a mental picture of them is rather like trying to photograph a rapidly changing kaleidoscopic pattern! They are twenty different things in so many minds—cavities in the æther, spinning violently and forming centres of strain in their matrix; nebulous whirlpools whose fields of influence gradually fade, just

as a noise becomes fainter as we recede from it; or again, points of attraction and repulsion almost without size, to be used as numbers and signs by the mathematicians; or, once more, individual particles with "inertia," like matter as we know it in higher forms, powers of expansion and increase of apparent mass when in rapid motion, and the possibility of a composite structure to be revealed to our further scrutiny.

This seems very confusing and dazzling, and the outlook was very much simpler a few years ago, when much less was known and guessed at, and men were content to wonder at the newly discovered constituents of the atom—these electrons and protons—and to trace the manner of their arrangement and behaviour in the various kinds of atom which they built.

Nowadays all that study seems to be very much set on one side, as the research presses on to the heart of the mystery and tries to resolve the very nature and being of the elusive particles. This is natural, and as man cannot grasp all points at once, he is forced to drop some out of his immediate hold whilst striving further. But it does not follow that all the work done is valueless. Undoubtedly the arrangement of elements in the Periodic Table according to their atomic weights answers to definite fact, and does represent the building of the Life-Force in definite ways, with electrons and protons, to form the atoms of different elements. Whatsoever these may prove to be, in their ultimate nature, they certainly are used, in a wonderful order and symmetry of form and number, to build the bricks of the Universe.

When we try to form a clear conception of this building process we shall inevitably harden it into a more

definite and clear-cut shape than could generally be found in Nature.

Just as, in following the arrangement of leaves according to the phyllotaxian numbers, as I tried to show in a former book, we have to make allowance for the manifold causes which alter and confuse the ideal arrangement, so I think we must expect, even in these earlier buildings, to find less precision than in the ideal form which we present to ourselves. But I believe it is a true ideal which has been patiently uncovered by Man, and it has been found to answer to facts and to elucidate very many difficult points as to the nature of the different elements and their relations to one another.

It will be worth our while to study with care and precision the building of the Life-Force in this stage of its creative work, and to follow the ideas and pictures in the minds of those whose researches laid it open for us.

It will be remembered that the Periodic Table consists of a list of the elements arranged in order of their atomic weight, that is of the weight of their atoms as compared with one another. The hydrogen atom is the lightest of all, and that of uranium, which is the last, is the heaviest; if we compare the weights of these two kinds of atoms we shall find that taking the hydrogen atom at a trifle more than 1, the uranium atom weighs a trifle more than 238. Why these numbers are not perfectly exact will be clear from the explanation given on page 29 when speaking of isotopes. But the point is that in this Table the atomic weights go on increasing steadily from lightest to heaviest.

There are indeed one or two special cases where a slightly heavier element is put before a relatively lighter

one ; for example argon with an atomic weight of 39·9 is placed before potassium whose atomic weight is only 39·1. But the reason for these slight deviations from the regular order will be clear presently.

This arrangement of the elements according to their atomic weights was first made by the Russian chemist Mendeléeff about 1870, though the subject had been studied for some time previously, and the resemblances of certain elements in their chemical properties had been noted.

As soon as a definite order had been brought into the list of elements, it became obvious that the related elements occurred at fixed and definite intervals, and that there was some kind of meaning and order in this recurrence. It was seen that the elements in the list arranged themselves in *periods*, and that the members of one period had definite relations with the corresponding elements in the next. The first period consisted of two elements only. The second held eight elements, and every member of that period of eight had similar chemical properties with the corresponding member of the next period, which also held eight members. Thus No. 3, lithium, was related to No. 11, sodium, No. 4 to No. 12 ; No. 5 to No. 13, and so on. It was found that there were two periods of 8 members, two of 18 members, and one of 32. The remaining elements were apparently an unfinished period which broke off after the sixth element.

Until the coming of the new knowledge as to the structure of the atom and the electrons and protons of which it was built, there must have been many insoluble puzzles about this arrangement. Both the varying weight of the atoms of elements and the regular group-

ing of these elements must have been mysteries, and the relations of the members of different periods one to another a still greater perplexity. But light came rapidly with the discovery of electrons, following on that of radio-activity which opened the door of the atom and showed something of its constitution.

Although I have already touched on these discoveries, this having been a necessary preparation for the study of radio-activity, yet we must now go more thoroughly and carefully into the subject, and try to see the inner meaning of the grouping of the elements and of the periodic recurrence of similar properties.

It will be remembered that the atoms were likened to miniature planetary systems having each a nucleus composed partly of protons or particles of positive electricity, and that from the first element, hydrogen, to the last, uranium, in regular procession one more free electron is added to the circling planets around the nucleus, with each succeeding element. Thus hydrogen has but one circling electron, whilst uranium has 92 within its atom. But the nucleus, as I explained, contains in every case after the first one, more protons than enough to neutralise the electrons which revolve around it, and these extra protons are associated with electrons of their own, and we called them " married " protons, whilst those which hold, by their attraction, the free electrons circling round them, we described as the " unmarried " with lovers.

Now as we pass up the Periodic Table of Elements we shall find that the " unmarried " protons in the nucleus increase by one at each step, to answer to the new electrons circling round. This may be expressed by saying that the nucleus has a positive charge increas-

ing from 1 in hydrogen to 92 in uranium; and this is really of more importance than the atomic weight, though the two things march very nearly together all through the list. In just one or two places they do not keep quite in step, and then the weight has to be neglected in favour of the charge on the nucleus. So argon, with a heavier weight than potassium, is put before it, because the number of its free protons—that is its nuclear charge—is 18 and that of potassium 19.

TABLE OF ELEMENTS ARRANGED IN PERIODS AND ACCORDING TO THEIR ATOMIC NUMBERS WITH COMPARATIVE WEIGHTS.

		Weight.	
Period 1.			
1.	Hydrogen	1·008	Halogen
2.	Helium	4	*Inert Gas*
Period 2.			
3.	Lithium	6·94	
4.	Beryllium	9·1	
5.	Boron	10·9	
6.	Carbon	12	
7.	Nitrogen	14·01	
8.	Oxygen	16	
9.	Fluorine	19	Halogen
10.	Neon	20·2	*Inert Gas*
Period 3.			
11.	Sodium	23	
12.	Magnesium	24·3	
13.	Aluminium	27·1	
14.	Silicon	28·3	
15.	Phosphorus	31	
16.	Sulphur	32·06	
17.	Chlorine	35·456	Halogen
18.	Argon	39·9	*Inert Gas*

Period 4.	*Weight.*	
19. Potassium	39·1	
20. Calcium	40·07	
21. Scandium	44·5	Interpolated numbers
22. Titanium	48·1	begin
23. Vanadium	51	
24. Chromium	52	
25. Manganese	55	
26. Iron	55·8	
27. Cobalt	58·97	
28. Nickel	58·68	Interpolated numbers
29. Copper	63·6	end
30. Zinc	65·4	
31. Gallium	70·1	
32. Germanium	72·5	
33. Arsenic	74·96	
34. Selenium	79·2	
35. Bromine	79·9	Halogen
36. Krypton	82·9	*Inert Gas*

Period 5.		
37. Rubidium	85·45	
38. Strontium	87·63	
39. Yttrium	88·7	
40. Zirconium	90·6	
41. Niobium	93·5	
42. Molybdenum	96	
43. Unknown	—	
44. Ruthenium	101·7	
45. Rhodium	102·9	
46. Palladium	106·7	
47. Silver	107·88	
48. Cadmium	112·4	
49. Indium	114·8	
50. Tin	118·7	
51. Antimony	120·1	
52. Tellurium	127·5	
53. Iodine	126·92	Halogen
54. Xenon	130·2	*Inert Gas*

Period 6.		*Weight.*	
55.	Cæsium	132·8	
56.	Barium	137·37	
57.	Lanthanum	139	These are the Rare Earths (from 57 to 71). They form a long series of "interpolated numbers" not connected with previous elements.
58.	Cerium	140·2	
59.	Praseodymium	140·6	
60.	Neodymium	144·3	
61.	Unknown	—	
62.	Samarium	150·4	
63.	Europium	152	
64.	Gadolinium	157·3	
65.	Terbium	159·2	
66.	Dysprosium	162·5	
67.	Holmium	163·5	
68.	Erbium	167·7	
69.	Thulium	168·5	
70.	Ytterbium	172	
71.	Lutecium	174	
72.	Hafnium	—	
73.	Tantalum	181	
74.	Tungsten	184	
75.	Unknown	—	
76.	Osmium	191	
77.	Iridium	193·1	
78.	Platinum	195	
79.	Gold	197·2	
80.	Mercury	200·5	
81.	Thallium	204	
82.	Lead	207·2	
83.	Bismuth	208	
84.	Polonium	210	
85.	Unknown	—	Halogen
86.	Niton	222	*Inert Gas*
Period 7.			
87.	Unknown	—	
88.	Radium	226·4	
89.	Actinium	(226–227)	
90.	Thorium	232·1	
91.	Protoactinium	—	
92.	Uranium	238·5	

Last Period breaks off here.

The Table is now called the *Table of Atomic Numbers*, and the numbers are those of the increasing charge on the nucleus as we pass up it from element to element. It must be clearly kept in mind that the atomic number of any element gives the charge on its nucleus, that is the number of free protons calling to the circling electrons outside the nucleus (though, of course, within the atom).

The question which now presents itself is that of the arrangement of the electrons which circle round the nucleus, and the sort of orbits which they each have.

And here I must frankly confess the noise of conflicting theories is very great indeed and, at first, terribly bewildering. All the great minds of the varying groups of specialists are proposing theories to which others will find fatal objections, and then some new solution is propounded—to be immediately torn to pieces by another set !

Remember that the pattern and the movement of these whirling particles, the energy they give out and the energy they retain, all have to agree with proved facts in the great body of scientific knowledge, and it is no light matter to have " laws " which have been accepted like those of the Medes and Persians, set at defiance by the movement of ultra-microscopic particles within an invisible atom ! Yet this is what is happening continually. But these men of science are truthful before all else, they will " prove all things " and are willing to give up their dearest beliefs if a greater and more embracing Truth requires it. And we can but reverence such an attitude.

Meanwhile amongst conflicting voices and the noise of theory against theory and facts hurtling like spears

to kill one nascent idea after another, one still may catch that wonderful vision of the great Wheel of Life which all are seeing from different angles, and each trying to fit into his theory.

One sees the electrons like whirling sparks revolving on themselves as they fly in a wonderful mazy dance around their central sun ; one sees their varying orbits of all shapes and sizes, from swelling circle to narrowest ellipse, never returning precisely on their track but looping a double course like a rosette as they pursue their flying way, and at the same time leaping, now nearer, now further from their centre and sending forth vivid sparks of energy like fireflies as they leap ; and the whole galaxy of these fiery satellites weave a pattern of unspeakable beauty and intricacy, different for each element, and faster and more furious as the number of electrons increases in the more complex elements, till the mind reels and the greatest thinkers are compelled to confess that here " the mathematics are beyond them."

Can we then form no idea of the building of the Life-Force in the atoms of the elements, beyond the facts of the number of particles employed in each case ?

I think we not only can but *must* if we are to enter into the meaning of the work and get a glimpse of how these things can be.

The body of explanatory facts which I am going to try to outline may not be literally and exactly according to the Ultimate Truth. Very likely these will have to be modified and corrected as knowledge increases ; but that they do form some kind of a true picture I think there can be no doubt. They do explain, they do solve mysteries ; things do fit in, with their aid, and most

certainly we are justified in using them as steps to a true knowledge, and when clearer ways are opened, we shall have no difficulty in adjusting our ideas to meet them.

We must now visualise the free electrons circling round the nucleus of each element, as arranged in *groups of rings*. The electrons in these groups will not be all at the same distance from the nucleus, nor will there, of course, be the same numbers in each group. They will, in fact, gradually develop fresh rings or circles to accommodate the increasing numbers of electrons as we pass up the Periodic Table of Elements.

The first group to be formed—that closest to the nucleus—will consist of only one ring or circle, having two electrons upon it. Hydrogen contributes the first electron and this group will be completed in the element helium, with two circling electrons. This marks the end of the first Period in the Table of Atomic Numbers.

The next element, lithium, having its first two electrons arranged exactly like those of helium, on one ring, has to place its third electron on a new ring all by itself. A lonely position? Yes, and the new electron seems to feel it so, and tends to fly off to any outer attraction that may bid.

In the next element, beryllium, there are four electrons, and now there are two on the new ring to support each other. In the following element another ring is begun in this group with a fifth electron; and the sixth will be placed on the same ring, in the next element. In this manner the building goes on till at the tenth element, neon, the pattern seems to be complete with four rings in the group. The second

Period ends here, and—as one may say—that story of the building is finished.

We see that the eight electrons in the group just completed are not all revolving on the same plane, but on different circles, some nearer, some further from the nucleus, but still they form one group; with the first group of two (arranged like those of the helium atom) which lies nearest to the nucleus, these ten build up the second story of the edifice, complete in neon, the tenth element.

Thus, as the building proceeds, we see electrons placing themselves to form rings by their circling orbits; the rings—at different distances from the nucleus—uniting to form groups; and groups building themselves into more and more complex elements which at the end of each Period seem to form a perfect pattern towards which they have been striving all through that Period.

The third story of the building begins like the others. In the eleventh element, sodium, after its first ten electrons have been arranged in two groups with four circles like those of neon, the eleventh has to be put all by itself on an outer ring which is eventually to form one of a group holding eight electrons; and there is the same instability in the case of the lonely electron, and the tendency to be detached by a strong call or attraction from without. Number 12, magnesium, puts a second electron upon that same ring, and gradually eight electrons are added on further rings and we come to the completion of the third Period, or story of the building, in the eighteenth element, called argon, with seven rings.

Now, having got so far, a light seems to dawn on us,

making clear the reason for the similar chemical properties of the elements which answer to one another in the different periods.

A few diagrams of the patterns in which we may suppose the electrons to be arranged in the different

DIAGRAM 1.—First in set of three elements, viz., helium, neon, argon.

DIAGRAM 2.—Second in set of three elements, viz., helium, neon, argon.

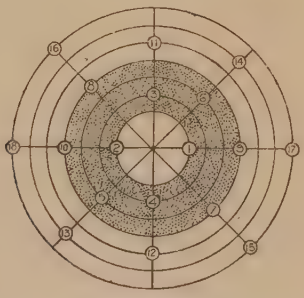


DIAGRAM 3.—Third in set of three elements, viz., helium, neon, argon.

elements, will help us to recognise the resemblance between those of the related elements in the different periods. We must, however, bear in mind that such diagrams are only a way of visualising a fact which cannot really be pictured; in fact they are merely symbols of the Truth, used to help us to grasp it more easily.

In using these diagrams there may at first be some difficulty as to the meaning of the wheels of alternate shading and white. These wheels, in the more complex

DIAGRAM 4.—First in set of three elements, viz., lithium, sodium, potassium.

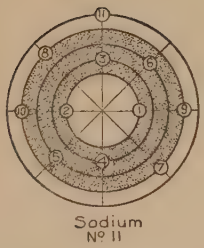


DIAGRAM 5.—Second in set of three elements, viz., lithium, sodium, potassium.

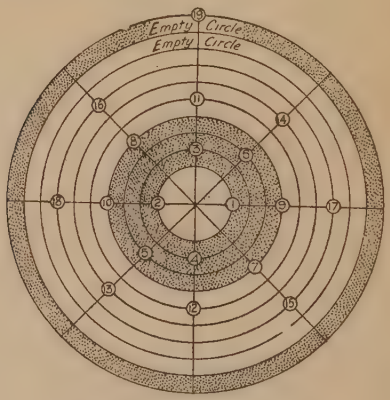


DIAGRAM 6.—Third in set of three elements, viz., lithium, sodium, potassium.

elements, do not always correspond with the Periods of the Table of Atomic Numbers, as will be seen; this may, at first, cause some confusion, but it must be remembered that each diagram is that of a particular

element, and the wheels concern the actual process of the building of that element—the way in which the electrons are grouped as the structure becomes more complex. Their full meaning cannot be understood until this matter is discussed and explained as will be done further on.[1]

The diagrams first given consist of the elements in which the first three Periods are completed, helium, neon and argon ; and beside them the three elements which begin the following Period in each case, namely lithium, sodium and potassium, which last begins the fourth Period. One cannot fail to be struck by the likeness between the patterns of the last three, each with its solitary electron starting on a new ring, and wavering in its unsupported loneliness.

Of course as the patterns are all built on the same plan, so far as we have gone, the other related elements will also have patterns that resemble one another. Thus we begin to understand that the chemical properties of elements depend in some way upon the disposition and arrangement of the outer electrons, which are added one by one to the pattern around the nucleus in their atoms, as we pass along the Periodic Table.

The fourth Period or story starts with potassium, and a fresh ring is begun in the old way and two electrons are placed on it. But please note carefully in the diagram of potassium that two rings in the third wheel are left completely empty, the nineteenth electron jumping over them to begin the fourth Period.

Suddenly there is a change, and the building of that ring stops. There appears to be, during the building of the next eight elements, an internal upheaval.

[1] See page 73.

Nothing happens at the outside of the atom; work seems to have ceased there, and the new electrons are crowding into the empty circles in the third wheel, and filling them up. There is considerable disturbance of the orderly arrangement which has been observed hitherto, the symmetry of the pattern is rudely disturbed and none of these eight elements (with the possible exception of the first one, scandium, No. 21,

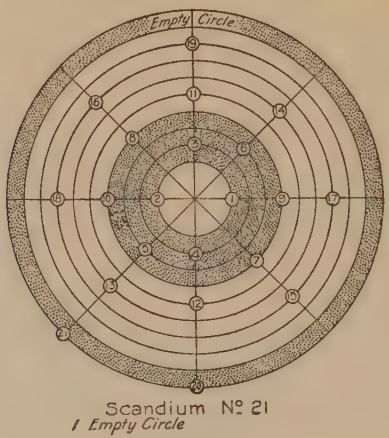


Diagram 7.

which has some relation with Nos. 5 and 13), have any connection with any which have gone before, as you will see from the diagram of krypton where the related substances fall into lines radiating from the centre.

This is a remarkable crisis in the building which has gone on so straightforwardly hitherto, and naturally it was a puzzle to those who first discovered the new departure, without, as yet, having the key to its mean-

ing. It was Professor Bohr who first arrived at the conclusion that a work of consolidation was going on, and that the eight members, from scandium onwards, were occupied with the rearrangement and strengthening of the earlier part of the building. Professor Bohr likens the incident to the formation of a " wound " in the constitution of the atom (the empty circles left

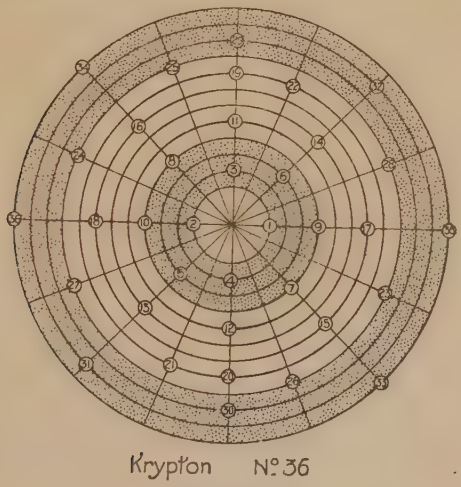


Diagram 8.

unfilled) which is gradually healed. This is not entirely accomplished until the appearance of the thirtieth element, zinc, after which work on the outside of the atom can begin again.

We shall have to seek an immediate cause for this episode when we come to consider the different forms of orbits in which these electrons are moving. Meanwhile let us note that though during the earlier periods it has

seemed as if the architect of Nature built each element by taking the previous one and adding one new electron to the pattern laid down, it is not so in reality. Each new element is a new problem, and it may involve—as we shall see more clearly later—the alteration of the pattern and rearranging of the later electrons, though the " core " or heart of the pattern does remain the same in all.

These eight numbers (from 21 to 28 inclusive) are called " the interpolated numbers " and similar series are to be found in the fifth and sixth Periods with the same cause. Perhaps in all building of the Life-Force there is something analogous to this pause with a period of secret consolidation. It is a subject worth thinking over and might afford a clue to many periods of apparent stagnation, stationary states when no growth is perceptible, and disappointing pauses after brilliant promise.

To return to the building of the fourth Period. No more structure is added on the old lines till after the filling of the empty circles into which the eight interpolated numbers have crowded, bringing the number of its electrons up to 16. There is actually room for 18 in these circles, and the eighteenth is finally placed at No. 29, copper, with a temporary displacement of electrons, one of those already placed in the fourth story being taken and used temporarily to finish the expanded third ! You may notice that this leaves copper with *one* electron on the first circle of the fourth Period just like potassium and sodium ; and copper has chemical properties somewhat similar to these as we might expect.

From this element onward, the work of the fourth

story proceeds regularly, and on examining the diagram of krypton you will notice that by the time this element has been built up, the empty places in the third wheel have been filled; the "wound" (as Professor Bohr describes it) has been healed, and the symmetry of the atom is completely restored, so that, merely by looking at this diagram you would never guess what a

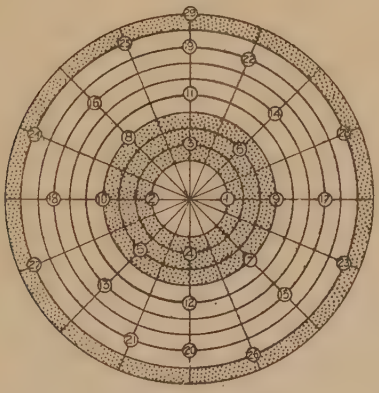


DIAGRAM 9.

rough break there has been in the architecture of the elements leading up to it. You will see that in the final arrangement of electrons in the completed pattern of krypton, the eight interpolated numbers fall into their places in the third wheel between the other numbers, showing their disconnection with any that have gone before. Copper, No. 29, is finally placed on the line with lithium (No. 3), sodium (No. 11), and potassium (No. 19), with all of which it has some chemical relations,

and the rest fall into line with the members of the earlier groups.

The diagram of krypton was originally worked out by me with a special purpose in view, and I will pause for a few moments to describe it, as it bears strongly on the subject of the building of the Life-Force throughout all creation.

In a former book (*The Life-Force In The Plant World*) I have described my efforts to prove that the phyllotaxian numbers—a series according to which the leaves of plants are placed in spirals upon their stems, each plant having a definite rhythm and arrangement proper to it—may be still read where the plant has its leaves in whorls or circles instead of the spiral form up the stem. I cannot here go into this subject or explain my view, but when studying the building of the elements which I have just described, I was forcibly struck with the idea that the same series of numbers arranged in a spiral might lie at the root of the patterns traced by the electrons around their nucleus, and I set to work to make diagrams and test the idea. In the end I worked out the model here depicted, which seems to answer to the requirements of the theory regarding the building of the elements, and to show clearly the periodic likeness in chemical properties of certain elements, and also to exhibit the way in which the interpolated numbers spring forth without precedent or likeness to anything that has been heretofore. And in this model I have been able to read one of the phyllotaxian series as far as element No. 21, where it breaks off, as it is bound to do, since the orderly building is here interrupted.

In this connection the remark of a Professor of Geology (Sir Edgworth David) passed on to me by a

correspondent, is both instructive and suggestive. "Crystals," he writes, "are rarely spiral as regards their outward shape, but internally, as regards their molecular structure, they must be spiral, as they cause (*i.e.*, many crystals do) vibrations of light passing through them to spin. This is called 'circular polarisation.' For example, quartz and sugar crystals both polarise light and must therefore be spirally constructed."

Since making my diagram of krypton I have made the interesting discovery that in 1862 Chancourtois, who appears to have been the first to observe the recurrence of special types of elements at regular intervals when arranged according to their atomic weights, "arranged the elements in a spiral round a vertical cylinder whose surface was divided into sixteen vertical sections. The elements situate in any vertical column were seen to possess analogous chemical and physical properties. This arrangement became known as the Telluric Screw." (Dr. J. N. Friend, *Modern Inorganic Chemistry*.)

Since Chancourtois' time various other spiral arrangements of the Table have been proposed.[1] This merely means that it is possible to express the list of elements, as gradually built up by the Life-Force, in a spiral, showing definitely recurring characteristics at stated intervals. Now this is exactly the way in which leaves of plants are arranged normally upon a stem (though the law is often masked by opposing circumstances), each plant having its own interval of recurrence, so to

[1] Professor B. Smith Hopkins in *Chemistry of the Rarer Elements* says that Lothar Meyer "suggested a spiral arrangement, which has the advantage of showing both the continuous nature of the scheme, and the periodic recurrence of certain properties."

speak. And here, in the building up of the electrons around the nucleus to form an element, I trace the same principle of the spiral with recurring characteristics as shown in my diagram. Surely this is a striking example of the same principle of building recurring through the work of the Life-Force from the very beginning of the work in the inorganic to the high development of organic life.

We shall not go through the building of the fifth and sixth story, which is somewhat on the same lines but, of course, more complicated, and, in the case of the sixth Period, having a long series of interpolated numbers, called the "Rare Earths." These elements, from No. 57, lanthanum to No. 71 lutecium, are all very similar in their properties, and this is to be explained by the fact that during the filling up of the inner circles (as in the case of the interpolated numbers beginning with scandium, described above) no change takes place in the outer shell of the atom, because all the new electrons are being used in the internal building. Changes in the outer ring or shell of electrons are those which cause changes of chemical property in the elements.

The few remaining elements form part of a period of which the members were apparently too complex to have stability. Amongst these are the radio-active elements which are constantly breaking down and resolving into simpler forms. In fact it seems as if the building of more and more complex patterns had gone as far as was possible, notwithstanding the precautions taken by the inweaving of the interpolated numbers.

CHAPTER V

THE PATTERN-BUILDING OF THE ELEMENTS

Synopsis of Contents: Importance of stability: Pattern-building of elements an effort to attain it. The perfect patterns of "Inert gases." Relation of their respective numbers. Incompleteness of the elements which lie between the inert gases. Reasons for this and for perfect stability of inert gases. Nuclear electrons not involved in the effort after stability; changes in the nucleus resulting in disintegration of the atom. Shapes of the orbits in the outer electrons. Reasons for these. Another effort after stability. Orbits of certain electrons considered and explained. Diagrams. The atom in its stable state. "Ionised" atoms and resulting imperfect stability.

We have realised by this time that the most important point in the building of elements is the *stability* attained. Obviously it is of no use to build if the structure is liable to break down at once; and if the elements are to be at the foundation of all things, they must be built securely and strongly. The wonderful patterns we have been examining all aim at such stability, and we shall presently see that the combination of the atoms of different elements to form compound substances is brought about by this same effort after stability. Meanwhile let us look once more at this orderly arrangement of elements which we have been considering.

There are in all 6 complete periods (the 7th is unfinished) and each of them ends in a perfect and symmetrical figure. The names and numbers of these latter are: No. 2, helium; No. 10, neon; No. 18, argon; No. 36, krypton; No. 54, xenon; and No. 86,

niton. Each is a gas, and they have this peculiarity, that their patterns are so complete and well-balanced that none of their electrons show any desire to escape to other attractions; their stability is perfect and the atoms of these elements show no disposition to combine with any other kind, being stable and complete in themselves. These are the "Inert gases," or as the Germans prefer to call them, "The Noble gases," being above the common need which draws element to element.

At first sight the atomic numbers of these gases do not seem to suggest any order or regularity in the growth of the buildings: yet there is an underlying meaning and order. The numbers are 2, 10, 18, 36, 54 and 86. Now the difference between each of these numbers will, of course, be the number of electrons that were used to build this story of the edifice; thus from helium No. 2 to neon No. 10 is eight, so the number of electrons required to build the second story was eight; from neon to argon eight again were used; from argon to krypton eighteen, from krypton to xenon eighteen again, and from xenon to niton thirty-two. Now put these numbers side by side, and you will find that if you start with the number 2 and multiply it twice by one, two, three, and four respectively, you will get the numbers of these groups of electrons forming the "perfect" gases.

Here is the sum: the numbers of electrons used in the different groups building up the inert gases are 2, 8, 8, 18, 18, 32.

Two x 1 = 2 x 1 = 2
Two x 2 = 4 x 2 = 8 twice repeated
Two x 3 = 6 x 3 = 18 twice repeated
Two x 4 = 8 x 4 = 32

This little sum will give a hint of a regular order of progression lying at the root of the building we have been studying, though all that it implies may not be very clear at present.

What does come out sharply and distinctly is that the numbers 2, 8, 18 and 32 are those which can be arranged in the most stable and well-balanced patterns, and it is therefore obvious that those elements which lie between the inert gases, and have more or less electrons than these in their building, are less secure and more liable to some form of instability. The building up of these stories is a precarious business. The elements which have to start a new one, such as lithium, sodium and potassium, find their new electrons on the outpost very hard to keep (see diagrams), and on the other hand elements whose atoms have only one or two electrons wanting in order to attain the number of the next complete story (such as oxygen which needs two electrons to reach the stability of neon, or fluorine requiring one) tend to pick up one or two electrons from wherever they can.

We must not suppose that when these things happen the atom in question has solved all its problems and is in a state of stability like the inert gas whose number of electrons it has acquired. A perfect pattern is not the *only* consideration, and an atom of sodium which has lost its eleventh electron and has only 10, like neon, has an unsatisfied proton in its nucleus calling for the lost electron, and creating a different sort of instability by its discontent. In fact the whole atom is now to some extent unbalanced, wanting a negative charge (an electron) to neutralise its extra positive charge (the proton in the nucleus). On the other hand an atom of

fluorine which has picked up one extra electron, has now one unsatisfied negative charge for which there is no response in the nucleus. So we say the sodium atom has become positively charged and the fluorine atom negatively charged, and each will be to this extent unbalanced and unsatisfied.

The inert gases are in a state of stability mainly because they are so lucky as to have the numbers of unmarried protons in their nuclei and of electrons balancing these, which are required to build perfect patterns, viz., 2, 10, 18, 36, 54 and 86.

It is very important to keep in mind that all this losing and gaining of free electrons which goes on in the atoms of elements is quite independent of any change in the *nucleus*. An element may lose several electrons from those circling round the nucleus of its atom, or may gain an equal number, but the atom will still be an atom of the same element, only it will have become positively or negatively charged. But take an electron from the nucleus and it is a very different story. The whole constitution of the atom is changed, and as we saw in radio-active elements, the shooting forth of a proton or electron from that " inner fortress " results in the forming of a different element.

An electron taken from the nucleus must come from the " married quarters " described in the chapter on radio-activity, and though the call of the now positively charged atom may bring a new electron to it, this will never be permitted to enter the nucleus or to take the place of the lost one, but will remain circling round. Consequently there will be one more *nuclear charge*, because the married proton whose partner is gone will now be a single proton calling to a lover, and as we know

an extra nuclear charge means that the atomic number has gone up by one and a new element is formed.

It will therefore be clearly understood that all this building we are now describing, the patterns woven and the losing or gaining of electrons in the ceaseless effort after stability, is concerned entirely with the outer or free electrons which " weave their mazy dance " around the nucleus.

The strong call of the nucleus is the main force which binds all this whirling cloud of electrons into one and forms the atom. From the single electron in hydrogen rushing round its nucleus at a rate of 180,000 miles a second, to the 92 in uranium, all are subject to its

DIAGRAM 10.—An ellipse with nucleus at one end.

influence and held by its attraction. In the later elements, as the number of electrons increases, the call of the equally increasing number of protons in the nucleus grows stronger and the atom does not increase in size to the extent we should expect, the radius of xenon, for instance, being less than twice as great as that of helium.

Let us now consider for a few moments the different shapes of the orbits round the nucleus which the individual electrons are pursuing. Not all are circles; many of the electrons are travelling in long ellipses with the nucleus at one end.

The third electron in lithium and the eleventh in the sodium atom have this kind of orbit, and though at one

point they are rushing very close to the nucleus (they do this bit of the journey faster than the rest), yet at the other end they are far away and one can understand the danger of their flying off to other attractions.

Why do the orbits vary like this ? It is really another kind of effort after stability. Though we cannot go into the subject very fully, yet a few observations will make it clearer. We must remember that all electrons tend to repulse one another, each being a negative particle of electricity ; every new electron, therefore, which joins the group round the nucleus has to find the position in which it will be best reached by the attraction of the protons in the nucleus and least repulsed by its fellow-electrons. In the case of lithium the third electron finds the nucleus guarded by two others in circular orbits whirling around. If it tried to circle round just outside them it would be terribly screened from the " rays of its sun," so to speak, by their patrol. So what it does is to make a dash through their circling guard and travel very close to the nucleus for a space, and then flash out beyond them for the rest of its journey. In this enlarged orbit however (answering to its position on the new ring, in the diagram of lithium, which see) it is much more easily detached from its allegiance to the proton in the nucleus to which it belongs. So much so that if the force required to remove an electron from the helium atom is 25 volts of electricity, that which is needed to remove this electron from the lithium atom is only 5 volts ! Every increase of nuclear charge affects the problem as to the orbit of the new electron in the building of the new element, so the next element beryllium, has its new electron more firmly bound than that of lithium.

The case of the elements just before, and at the crisis which resulted in the interpolated numbers, can be interpreted and explained on these lines. The element potassium (No. 19) finds itself in the same sort of predicament as lithium did when it comes to place its nineteenth electron. The eighteen before it " shut off the sun's rays," so to speak, almost completely, and the

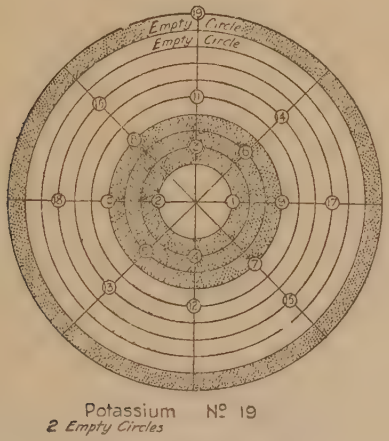


DIAGRAM 6 repeated.

nineteenth element resorts to the same device that the third did, and makes a long elliptical orbit. But to do this it skips over two of the circles (which will have to be filled later) and goes to an outer one, as will be seen in the diagram of potassium. The twentieth electron in the next element does the same, but when scandium (No. 21) comes to be built, the new protons in the nucleus to match the 2 last-added electrons have

greatly strengthened the force of attraction outside those 18 electrons, and scandium can put its nineteenth electron on the circle left vacant (where it has a circular orbit) but its twentieth and twenty-first have to go on the outer circle with long elliptical orbits because the nineteenth is making a screen again !

Each new element, as it comes to be built, thus sets

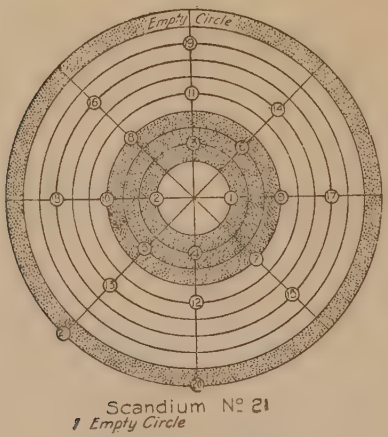


DIAGRAM 7 repeated.

a new mathematical problem to be solved, the aim being always to attain the greatest stability—an aim always reached periodically in the pattern of the next " inert gas."

Professor Sullivan, in his book, *The Basis of Modern Science*, says : " Bohr related the periodic properties of the elements to the types of orbits in which the outer electrons of the atoms revolve. These orbits fall into

families, the same family recurring for the members of the same periodic group."

The diagrams here given, which as I have said, can only be regarded as symbols of the truth, represent the atom in its most normal and " unexcited " state. But various outside influences, such as an electric current or a beam of light falling on them, may at any moment affect one or more of the electrons, causing them to spring from one of the smaller circles near the nucleus to a larger circle further out. This they do by absorbing energy from the exciting cause, whatever it may be. When this is removed the electron or electrons may return to the smaller circle to which they belong, and as they do so, they will emit a flash of light which is in proportion to the energy which they received from the disturbing cause.

If the latter is very strong, as in the case of X-rays, it is possible to detach even the more firmly bound electrons from the circles near the nucleus and to expel them from the atom. In this case the atom becomes positively charged or " ionised," because the nucleus will have an unsatisfied proton left calling for the electron which has been banished.

It will perhaps be remembered that the α-particles escaping from radium came out positively charged and calling for electrons to fill the vacancies of those they left behind. In passing through gases they acquired these electrons by knocking them out of the atoms of the gas, thus leaving those atoms " ionised " or positively charged. The most stable elements are those, like the inert gases, which hold their electrons so firmly bound that it requires an enormous force to detach one of them.

From these remarks it will be seen that the more unstable elements, such as sodium and potassium, have a great tendency to become ionised by various outside causes, and that in taking on the pattern of the preceding inert gas they do acquire a certain increase of stability in spite of their positive charge. In the next chapter we shall see how this condition leads to further building operations.

CHAPTER VI

THE BUILDING OF MOLECULES AND COMPOUND SUBSTANCES

Synopsis of Contents: (1) Object of this book to follow the working of the Life-Force from earliest known stages of the Creative Energy. Limitation of the field to this purpose. Unanswered questions not merely at the start, but strewn along the way. Unexplained key-numbers or "constants." Improbability that we can ever "touch bottom." Hidden Truth, like the central spiral of fircone. Value of the search, and its effect on men of science. In the Inorganic, life cradled by the Life-Force, in the unborn state, preparing for birth. Résumé of the way we have come so far. Explanation that helium and hydrogen atoms are probably the main building blocks of all elements. Description of arrangement of electrons in the inert gases with the last ring in all cases consisting of eight electrons. This insuring stability through consolidation of the mass nearer to the nucleus.

(2) Formation of molecules in certain simple elements by the combining of two or three of their atoms. Compound substances composed of two or more kinds of atoms forming molecules. Definition of molecule. Binding forces of the electron and of the molecule. The electrical force or call of electron for proton and of proton for electron. Its effect in binding the atoms of the elements, and the process described. Positive and negative ionisation of atoms. Union of positively and negatively ionised atoms resulting in a perfect pattern and stable electrical balance. Aim of all elements (except the very early ones whose stable pattern is 2) to complete their ring of eight or "octet." Where electrical exchange not an available method, sharing of electrons resorted to. These two methods described as "electro-valency" and "co-valency." Co-valency described with diagram. Resulting stability explained. "Co-ordinate links," and their use and meaning. The building up of a complex molecule. Diagram and explanation of molecule of sulphuric acid. Stability of molecules so built up. Valency electrons of the "interpolated numbers" and "rare earths." Special cases considered and explained. Summary, and some explanation of the problems of the building and causes of chemical effects.

§ 1

In a book like the present one, which is neither a catalogue of scientific facts nor a description of the

present state of knowledge, but an attempt to follow, however imperfectly, the working of the Life-Force from the earliest known stages of its creative energy, very much must of necessity be left out. Whole fields of knowledge and adventure lie on either side of the way, and tempt us to explore where man is blazing his trail, yet we must not forsake the path we have marked out, and must only use material which is immediately relevant to our object.

We are striving to follow the actual building of this world from the first beginnings which have as yet come within man's vision. We have watched the atom—which for so long was the limit of his sight—break up and show us a whole world within its minute sphere ; we have recognised the protons and electrons which build it, as atoms of electricity, and the rays which proceed from radio-active elements as containing atoms of radiation, and even light-waves as probably consisting of atoms of energy, or properly speaking of " action." And at all these points where knowledge ends we know that we have not reached bottom. We know that electrons and protons exist, and that they attract one another and repel their own kind (except in certain magnetic conditions), but as yet we have no further certainty, though there are glimmerings of light as to the constitution of electrons, and there is probably much further work to be done as regards the nuclei of atoms and the protons therein. But even supposing that some day we are able to see all Creation as evolving out of some one, all-pervading " ethereality," such as the imagined æther, even there the first beginning will escape us, and we shall still stand with a question in our minds.

These unanswered questions seem to lie strewn all along the way, and not merely at the opening of the creative action. In working out the problems of the lines in the spectroscope, which answer to the different elements and help to explain the movements of the electrons within the atoms (this is one of the subjects we have had to pass over) physicists have come upon a certain fixed number which has been found to act as a key to important laws, and has opened the door to an explanation of these subjects. Exactly the same thing has happened with regard to the study of waves of light and of radiation, and a key-number has been found which has again opened doors of knowledge. These numbers are called " constants," but how they arise and why they can be used in the way discovered, is utterly unknown. It just *is* so, as two and two are four! No doubt many of these questions will be answered sooner or later, but as to the notion that we can ever touch bottom, I must fall back on my old theory of life, symbolised in the fircone (and fully described in a previous book), in which the Secondary Spirals are patent to our sight and can be followed from bottom to farthest tip, yet none of them take in all the scales of the cone, that being reserved for the hidden, unseen Spiral which wends its way up in secret, taking into its great coil every single individual scale of the cone.

We have tried to begin our study at the beginning of our present knowledge, but exactly where we begin to watch the Life-Force is not so important as the spirit in which we do so. Seers and saints, mystics and theosophists have sought persistently for the " heavenly vision " and have for the most part expected

doors to open in the sky. Yet doors are opening under our feet, and the "heavenly vision" in its great beginnings is being granted to physicists and chemists and men of science, though often they know not what they see. Its reflection is in their faces and in their characters, it inspires their passion for truth, the intense importance they attribute to perfection of detail in all their work, the strangely self-sacrificing spirit shown by them as a class, their frequent indifference to fame and wealth and all the things that most men seek, their great unselfishness and even for the most part freedom from jealousy.

All these things come from the persistent study of the Heavenly Vision of the Life-Force as it builds the beginnings of the world. Could we do better for ourselves or our children than to watch and teach them to watch the work of the Heavenly Architect? Often it needs patient and persistent work even to follow where men of science have hewed the way—giving their lives in the service—yet surely it is worth while. No "Materialist" can afford to neglect this study, for all is built upon it, and the Life-Force builds securely and makes its foundations sure.

In the inorganic world Life is, as it were, yet in the unborn state and its "freedom" is as yet strictly and severely limited. Consider, for example, the difference between the assurance of the chemist combining two elements to form a known compound and that of the gardener applying the pollen of one flower to the pistil of another with the *hope* of producing a known and definite species in the seedling. How often the result in the latter case is disappointing; the freedom of the life has asserted itself and the end is no foregone conclusion.

In the world of inorganic matter the Life-Force is still cradling that which is to be, and though building with living bricks and instilling into them the breath of its being, whereby they are endowed with strange powers of attraction and cohesion, inexplicable to us, and the power to become in union that which they were not individually, yet their time of true liberty is not yet, and they must be built truly and perfectly in readiness for the great day of birth.

We have watched this process through the building of the atoms of all elements out of protons and electrons. We have noted the welding of the four protons and two electrons in the helium nucleus, a piece of prehistoric masonry wrought together at some immense expenditure of energy in the ages before Man was, and we have seen that they appear to be used as the main building blocks in all the elements after helium, and that in radio-active substances they can be seen to issue whole and unchanged in the form of α-particles from the nucleus of the disintegrating element.

In this connection it may be mentioned in passing that in elements whose atomic weight is not divisible by four, the odd number of protons is apparently made up by hydrogen nuclei (with *one* proton). For example nitrogen, which is No. 7 in the Table of Atomic Numbers, and whose atomic weight is 14, cannot be built up entirely of helium nuclei, containing 4 protons each, seeing that 14 is not divisible by 4 without a residue; so the remaining 2 protons are necessarily supplied by hydrogen nuclei. And this has actually been experimentally established by Rutherford, who bombarded various elements with α-particles (it will be remembered that these have immense velocity and penetrative force,

and a distinct range like bullets from a rifle), with the result that in *some* elements, of which nitrogen was one, rays were given off which proved to be hydrogen nuclei, driven forth from the nucleus of the nitrogen atom. This very important result seems definitely to establish the fact that the building materials used for all elements are helium nuclei (as proved by radio-active emanations) and hydrogen nuclei associated with electrons.

As the building process proceeded we have seen the extreme precision and orderliness of the arrangement of electrons outside the nucleus, and the exceeding and constantly increasing complexity of their pattern. The precariousness of the difficult building has been brought home to us, and we have noted the precautions taken by the Building Life-Force, to secure stability, noticeably the interpolated numbers, winding an inner circle, as it were, to strengthen the building before the outer work could go on.

We have seen how the varying orbits of the circling electrons weave the pattern more securely, and how, at stated points in the process of element-building, a structure is attained (in the inert gases) where for the moment a firm and stable state has been secured. Yet, unresting still, a new effort after still greater complexity immediately begins.

Finally we have realised that in these outer electrons of the unsatisfied elements (all those which are in process of building perfect patterns, and which lie between the inert gases), there is a constant unrest, and the atoms have a tendency to cast away the electrons which belong to a new bit of building when the element is one coming just after an inert gas, such as sodium ; or, on the

contrary, to acquire the requisite number when they belong to one coming just after the perfect pattern, such as chlorine.

One would naturally have thought that from beginning to end of the great building, each element would repeat the pattern and arrangement of the previous one, just adding one more electron to carry on the building a step further. However we have seen that this is not so. Comparing the diagram of argon with that of krypton, the meaning of the shaded and white wheels will now become clear and we shall observe that through the inweaving of the interpolated numbers, the third wheel, instead of having eight members like argon, has *eighteen*, and the fourth has the remaining eight. And in the building of the next inert gas xenon, with 54 electrons, this happens again and we find there are two electrons in the first wheel, eight in the second, eighteen in the third, and eighteen again in the fourth, leaving eight for the last. And in the last group of all that is completed, the arrangement is as follows: two, eight, eighteen, thirty-two, eighteen, eight, in the six wheels respectively.

So instead of the numbers getting larger in the outermost wheel, the plan is to crowd the inner ones and to keep to the number eight for the last wheel of all in every case. We can easily see that this makes for stability, for of course the attractive force of the nucleus diminishes with the distance of each new wheel; and there is comparatively little to hold these latest comers to their allegiance. In fact it is the eight outer electrons in all cases which are the most unstable and easily detached, as we shall see.

At this point we pass to a further act in the drama of

world-building, and come to the study of molecules and the combination of atoms to form compound substances.

§ 2

Many of the simple elements have their atoms quite separate one from another, though held together by forces of attraction. Others—especially gases, such as oxygen, hydrogen and chlorine—have a tendency to form *molecules* or particles consisting of two or three atoms stuck together as we might say.

All compound substances are formed of molecules, and the difference between simple elements and compound substances is this : in the former case if we break up the element (even such as form molecules of two or three atoms) into the atoms which compose it, every atom will still be the same as the substance we are analysing ; but if we reduce a compound substance to its component atoms there will be some atoms of each of the different kinds of matter of which the compound is made.

Thus silver or copper, sulphur or sodium reduced to their atoms would be found to have pure atoms of silver or copper, sulphur or sodium and no others ; but salt would be found to have two kinds of atoms, one of sodium and the other of chlorine in equal numbers. The atoms of sodium and chlorine in common salt are combined very closely, and if, without separating them, we examined one of these particles, we should find it was *salt* and had quite different properties from either the sodium or the chlorine which composed it. This would be a *molecule* of salt, the smallest quantity which could exist as salt, for if we broke it up further by

chemical processes we should reduce it to atoms of chlorine and sodium.

All compound substances are composed of such molecules built up of atoms of different substances, and totally different from the elements from which these atoms are taken. The molecule in a compound substance is always the smallest amount that can exist as that substance. If we reduce it further it loses its character and becomes atoms of the elements from which it was built. We must now follow the course of this building of the compound substances from elements.

In every case of building, whether we speak of the building of an atom or the building of an element, or that of a compound, there must be something to hold the particles together. This binding force appears to be some form of what is known as electrical attraction, or rather we might better say some unsatisfied condition of the particles of the two substances whereby the one cannot be satisfied without the co-operation of the other. But there is probably also a further binding by magnetism of which we must speak later.

Without such binding or attraction electrons and protons must drift through space, and there could be no "matter" and no stability. How and why the varying patterns of the elements arose is purely the secret of the Life-Force. I know of no conjecture as to the reason for the grouping of electrons and protons to form the patterns of oxygen or carbon, silver or lead. But that which binds the free electrons of an atom to its nucleus is the need of the one for the other, and the same invisible force joins atom with atom to form an element.

In the case of sodium and chlorine above mentioned,

the course of events would be as follows: an atom of sodium (which, you remember, is one of the unsatisfied elements following an inert gas, and impelled to give up its extra electron and go back to the perfect pattern of neon) would give its unwanted electron to satisfy the need of an atom of chlorine for one *more* electron to complete its pattern and become like argon. Now the atom of sodium, having one less electron than it properly should have, will become positively charged (or ionised in technical language), because there will be an unsatisfied proton in its nucleus whose electron has been carried off, whilst the chlorine atom with the extra electron which it has stolen, will become negatively charged (negatively ionised). These two atoms will consequently attract each other and unite to form the molecule of common salt.

With certain elements in the first three periods of the Periodic Table this is a very usual way for the building to begin. The atoms of the two elements which are placed just *before* an inert gas are always wanting more electrons to complete their pattern, and the two immediately following such a gas tend to lose their extra electrons and go back to the pattern just completed.

Thus for example in Period 2, lithium would have one electron too many in its atom and beryllium would have two unwanted ones; these elements would tend to return to the pattern of helium by losing their superfluous electrons. Oxygen, on the other hand, requires two and fluorine one electron to reach the pattern of neon. In the first two cases the atoms of lithium and beryllium would become positively charged by losing electrons which answered to the protons in their nuclei; they would be "positively ionised" in technical lan-

guage, and would form positive ions. The atoms of the last two elements, oxygen and fluorine, would become negatively charged by receiving more electrons than the answering protons in their nuclei ; they would be said to be " negatively ionised " and to have formed negative ions. It is desirable to understand this process as clearly as possible before going further, and to realise how it makes for stability. It will be a help if the Table of Elements is constantly referred to during the following explanations.

Let us first take the two elements on each side of helium, the first inert gas. Lithium has in its atom three electrons and three free protons answering to them from its nucleus, hydrogen has one electron and one proton. If the atoms of these two elements meet, and an electron from the lithium atom passes to the hydrogen atom, the molecule which will result from the linkage of these two ions will contain four free protons and four electrons. The electrical equilibrium is perfect. That is one point towards stability.

Now as to the pattern of the inert gas helium. Is this being followed in the atoms composing the molecule we are considering ? In this very early stage of building, the " pattern " is so simple that it consists merely of two electrons placed at opposite sides of the nucleus. The atom of lithium has now reduced its electrons to two and the atom of hydrogen has increased its satellites from one to two. Both now conform to the number of helium and the " pattern " of both atoms of the molecule is complete and follows that of helium. This is the second step towards stability.

Take one more example. Sodium, in Period 3, has eleven electrons and eleven free protons. Chlorine in

the same period has seventeen of each. The sum of these two atoms will be 28 electrons and 28 protons. Now sodium's hope of stability is in forming the pattern of neon with ten electrons and protons, whilst chlorine can complete itself in the pattern of argon by obtaining eighteen electrons and protons. Since there are 28 electrons and protons in a molecule consisting of one atom of sodium and one of chlorine it follows that for one atom with ten electrons and one with eighteen the electrical condition will be in equilibrium, since 10 + 18 = 28.

I am making no statement as to the manner in which the two linked atoms share their electrons and protons or how the two nuclei affect their satellites. I am merely saying that the charges of positive and negative electricity in the molecule are even and there is electrical balance. The patterns of the two linked atoms are also perfect, each in its order. Sodium with ten electrons forms a group of eight outer electrons with a " core " of two, like neon, and chlorine with eighteen electrons forms a group of eight outer electrons, another of eight in inner circles, and a core of two, like argon. Both electrical balance and perfection of patterns are secured and there is stability.

As I explained before, the perfect gases, except helium, all have their patterns arranged in such a way as to have a group of eight outer electrons, and whilst this last group is being formed each element engaged in building it will tend in some way or other to complete the " eight of perfection " as we may call that group, or else (in the case of elements in the first three periods) to go back to the pattern of the former inert gas and find stability there.

Thus in the first period hydrogen will tend to obtain two electrons and to be like helium. In the second period all the elements will tend to go backward or forward ; the first two to return to the helium pattern and the others mainly to complete a group of eight like neon. In the third period the same conditions will exist ; but in the fourth the interpolated numbers will cause a central crowding of the atom, and between the first two, which will tend to return to the pattern of argon, and the last seven which will be impelled to complete the group of eight which is finished in krypton, there will be different conditions, of which I must speak later. In the fifth period (of eighteen members) the first two and the last seven will follow on the same lines ; the sixth period contains the very long series of interpolated numbers consisting of elements known as the " rare earths." We will only consider the first two and the last seven before the inert gas niton. In the last incomplete pattern only the first two will concern us.

In every one of the elements except those close to helium, which stand near to the inert gases, we find this tendency to complete the " eight of perfection " or the " octet " as it has been called, which is the last group of the previous or following inert gas. Leaving the elements which crowd the centre of the building in the later periods, we will consider only these neighbours of the inert gases. Naturally as each new group of circles is gradually built, the elements building it must acquire, one by one, the electrons to complete that group : thus hydrogen, lithium, sodium and potassium each have only one towards the new group ; beryllium, magnesium and calcium have two ; boron and aluminium have three, and so on. Now these are called their

" valencies " and we say that hydrogen and lithium are uni-valent having one valency, beryllium and magnesium are di-valent, boron and aluminium are tri-valent and so on.

These natural valencies are like hands to stretch out to other elements. When sodium with one valency electron gave its one valency electron to chlorine which had already seven, this completed chlorine's octet and left sodium with the octet of neon. But both atoms were ionised by the process and had to unite in electrical linkage to become neutral and stable again.

This process seems a simple and natural one, but on consideration we quickly see that it will not cover all cases. In the first place the linkage could only take place between elements in the opposite conditions of *wanting more electrons* and of *having too many*. But many elements are found to link their atoms although *both* are in the position of wanting more electrons. Also many gases amongst the elements, such as oxygen, hydrogen and chlorine form molecules of two linked atoms, and these must be precisely similar in every way, so that one cannot give, or another receive, an electron.

In the second place it is found that only certain elements are capable of forming ions as described above. Boron, carbon and nitrogen, for example, do not tend to lose electrons and become positively ionised, as lithium and beryllium do; therefore they cannot combine electrically with some other element with superfluous electrons which by passing them on can become negatively ionised. It is clear that some other form or forms of linkage must exist.

There had been some sort of theory as regards " valency " from the time of Berzelius (1812), but it

was to Kossel and G. N. Lewis working independently, that in 1916—a hundred years later—came the clearer views due to the new lights on the constitution of the atom. Kossel saw how the arrangement and pattern of the elements in the Periodic Table explained the give and take of electrons between them, and he was able to put the electrical theory that we have described above, in a clear and definite way. G. N. Lewis, on the other hand, saw light on the new problem as to how the molecules formed by gases or other substances having atoms similar in respect of requirement might complete their pattern. From him came the illuminating suggestion that it was possible for atoms to *share* certain of their electrons in such a way that the electron in question could belong to both atoms and complete the stability of each.

Suppose we imagine two seven-roomed houses placed side by side, the inhabitants of each being in need of one extra room. No. 1 may say to No. 2 : " If you will let my big boy share your lad's bedroom so as to set free his room, I will gladly let your husband share my husband's study for evening work when quiet is necessary." Each house would acquire an extra room and the two " linked " rooms would belong to both parties.[1]

[1] I believe no satisfactory theory as to the orbits of two shared electrons has yet been put forward. They belong, of course, to different nuclei and how can they do homage at the same time to their own " sun " and to that of the atom they are sharing with ? Probably this will be cleared up eventually. Meanwhile one might venture to speculate as to whether a double circulation might not exist ; the first chlorine electron having dashed round its own orbit, upon coming in contact with that of its sister might dash round *her* orbit whilst she meanwhile should fly round that of No. 1. Thus each would perform continuously a sort of figure of eight, which would lace the two electrons firmly together, the one always being in the opposite atom to the other.

Now two atoms of chlorine gas are in these circumstances. Each requires one more electron to complete its octet : an electron on each side approaches to fill the gap, so to speak, by sharing with the other atom, and both rings are complete in the resulting molecule. Here is a picture of the process as we may imagine it. This is called " co-valency " in distinction from electro-valency described previously.

It will at once be clear that no one can share what he does not possess : consequently atoms can only share their valency electrons whatever the number of

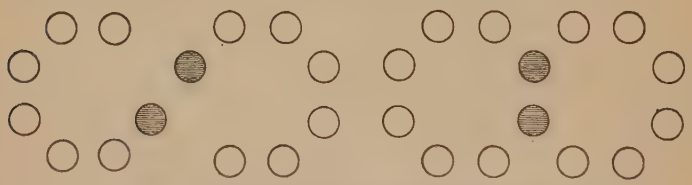


DIAGRAM 11.—Two atoms of chlorine sharing electrons.

these may be. In the above case chlorine has seven valency electrons but there is only space for *one* more electron in the octet, consequently only one is used and six remain unshared.

What would happen if chlorine should share some or all of these other valency electrons with other atoms ? We may say at once that every " illegitimate " electron that an atom may receive, that is every one beyond those required to complete its group of eight, will upset the electrical balance, and cause the molecule which is being formed to become ionised, or negatively electrified (usually an unstable condition as we know, but in some cases molecules thus ionised do seem to be stable if all

the octets of their pattern are complete). However, there are ways of sharing these valency electrons without upsetting the electric balance as we shall see. The six " hands " need not be useless.

Take another case of co-valency: carbon with four valency electrons can stretch out one " hand " to four fluorine atoms, each of which wants one electron to

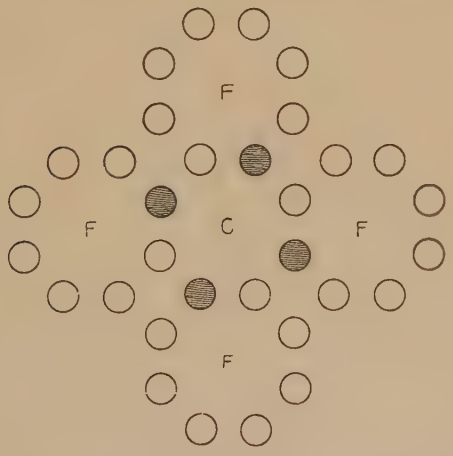


DIAGRAM 12.—One carbon atom sharing with 4 fluorine atoms.

complete its octet. Here is a diagram of the resulting molecule.

The four original carbon electrons in the centre are black and the fluorine white; it will be seen how the pattern is completed in each case by black sharing four whites, and white each sharing one black.

All theories of valency, whether electro-valency or co-valency, require that both of the combining atoms

or molecules should be " satisfied " or have their octets (in the case of hydrogen, the pattern of *two* only, not eight), completed. So in co-valency each partner *gives and receives* a share of one electron belonging to the other and thus gets one extra electron towards his octet. This insures stability which is the great object in all combining and building up of molecules.

However, even after the complete " satisfaction " of an atom which has combined with another, it is still in many cases possible for it to form fresh links of a different sort. They are no longer valencies, for all its valency electrons are used. But there may be still unshared pairs of electrons, as we noticed in the chlorine atom, after it had completed its octet by the help of another chlorine atom, and these pairs of " hands " can be stretched out to *give* though not to receive.

By this new method of what are called " co-ordinate links," the satisfied atom with a pair or more of unshared electrons can offer to share both of these—without any return—with another atom wanting two to complete its octet.

An example may make this clear and plain. Sulphur, which wants two electrons to complete its octet, shares one electron with each of two oxygen atoms, getting a share in one of the electrons of each oxygen atom in return. This is, of course, ordinary co-valency. On page 85 a picture of this part of the process.

Sulphur (black) is satisfied by having obtained a share in two oxygen electrons (white), but oxygen still requires one more electron in each case to complete the octet. We will suppose that each oxygen atom satisfies itself by sharing one electron with a hydrogen atom and receiving a share in one of its atoms in return. This

satisfies the oxygen atom and also the hydrogen (which wanted one electron) and now all the atoms in the molecule are satisfied and one might suppose the affair was finished. But the sulphur has, as you see, two pairs of unused electrons. Now it is possible for these to be used by means of co-ordinate links. Sulphur does not want any more electrons as its octet is complete,

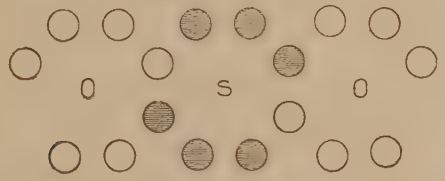


DIAGRAM 13.—Sulphur combining with 2 oxygen atoms. Sulphur is "satisfied" by having obtained a share in 2 oxygen electrons but oxygen requires one more electron in each case to complete the octet.

but it offers a share in its two pairs of unshared electrons to *two more oxygen* atoms, thus satisfying them. Now we have a very complex molecule (it is that of sulphuric acid) consisting of two oxygen atoms, having already a co-valency with hydrogen, joining with a sulphur atom, and two *more* oxygen atoms united to the same sulphur atom by co-ordination: thus:

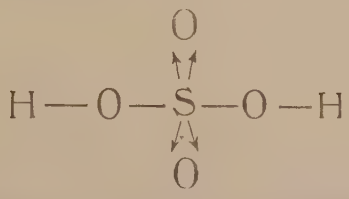


DIAGRAM 14.—Formula of the molecule of sulphuric acid.

Hydrogen, oxygen and sulphur are all joined by co-valency and the two oxygen at the top and bottom by co-ordination, the arrows indicating that sulphur has made a free gift to each oxygen atom of a share in two electrons.

Note that in cases like this, the atom which receives two shares in electrons and gives nothing in return has acquired a share in two extra electrons beyond its normal number, and thus must have something of a negative charge because it has offered no counterbalancing share on its side. On the other hand the atom that gives all for nothing has to the same extent become positively charged. (For this reason this linkage is sometimes called a semi-polar link ; electro-valency is a polar link.) The natural result of this would be that the two atoms would be drawn together by electrical attraction as in electro-valency, and the resulting molecule would be neutral and have great stability.

By means of these three methods, electro-valency, co-valency and co-ordinate links, the building of compound substances is carried on.

The valency electrons—that is those which are available for linkage with others—are, as we have seen, usually confined to those of the last group of eight in the elements of the second and third period and also in those at the beginning and end of the fourth, fifth and sixth periods. But even with these it would not be entirely true to say that there could be no more than eight in a group of valency electrons, or in other words that the atom of an element necessarily finds its final stability in an octet. This is certainly the usual plan, but in certain cases the atom of an element like sulphur, which has six valency electrons and normally requires

only two more to complete its octet, may share all its six with another atom by co-valent links, obtaining a share in six other electrons and so forming a group of twelve electrons. There are even cases where by co-valency a group of 16 are formed. Still, it will be seen that even where the final octet expands in this way in the compound substance, it is only the valency electrons of the combining atoms which are used. In the case above mentioned, sulphur had only two places left to complete its octet, but having six valency electrons, shared them all, obtaining six more, and so ended with twelve.

A few words must be said as to the valency electrons in the interpolated numbers and those of the rare earths, and their consequent powers of combination.

It will be understood that the valency electrons are those which can be easily detached from the atom by chemical means. It is also understood that the inert gases have such great stability that their electrons are never removed by chemical action—in other words they do not combine with any other elements. Now each of these has a final group of eight electrons, which is a very stable and firmly held arrangement. As long as there are only eight elements between the inert gases (as in Periods 2 and 3) the elements so placed will have, as valency electrons, the numbers which are building up those eight, and no more. But in Period 4, containing 18 members, after the first two elements the next eight are occupied in filling up the circles of the expanded third group which has been left empty. Here there are *two* incompleted groups, the third and the fourth, and in each element that follows, the conditions will be different according to the increasing

power of the nuclear charge on the one hand, and the position and kind of orbit forced on the new electron on the other.

In certain cases an electron placed in the last circle of the third group will be less firmly held than one on the first circle of the fourth group, and the valency will vary according to the varying conditions. Scandium, the third element in the fourth Period, and first of the interpolated numbers, does still follow the rule of the preceding Periods, and has three valency electrons like boron and aluminium, but the rest all have variable valency. These elements all have peculiar properties ; they are strongly magnetic and they have remarkable powers of inducing chemical combination between other elements. These, and other qualities are due to the incompleteness of the two groups which they are building up.

When we arrive at copper (No. 29) the third group is quite full and holds eighteen electrons in its different circles, and copper, having withdrawn one of the two electrons which the last element had placed on the first circle of the fourth group in order to complete the filling up of the third, now places its remaining one alone upon this new circle. Copper thus stands much in the position of lithium, sodium and all that group of elements. But there is this difference : the elements just mentioned have behind them an inert gas with a final ring of eight ; copper, on the other hand, has behind it a group of eighteen, and this, with the nuclear charge still as low as 29 is not a very stable arrangement. Copper tends therefore to lose not only its one valency electron, but also a possible further one from the rather unstable eighteen. The last six elements of this Period,

from zinc (No. 30) to the inert gas krypton, have the same valency and somewhat similar properties to those in the first two Periods.

In the fifth Period the building proceeds on very much the same lines as in the one just described. Rubidium puts its new electron on the first circle of the fifth group, leaving four circles of the fourth group empty. Strontium follows suit and at Yttrium (No. 39) the filling of the empty circles begins. Silver (No. 47) is the seventh before the next gas and thus holds the same position in this Period that copper did in the last, and it has one electron on the new circle (the first of the fifth group). It has a group of eighteen behind it just as copper had, but with the increase in the nuclear charge from 29 to 47 these are so much more firmly bound that no electrons are to be detached from them by chemical means and none of them are available as valency electrons, so silver has only one valency electron.

The next Period, the sixth, is that of the rare earths, and the conditions are very complicated. Whilst the fifth group has been started and three of its circles have been filled, the last two circles of the fourth group are still empty, and in xenon, the inert gas (No. 54) there is still a secret wound, so to speak, behind the last eight.

Meanwhile the first element of the new period rushes gaily off to the sixth group, leaving not only these two circles of the fourth group, but also two of the fifth group unfilled. So here are *three* unfinished groups to be dealt with. After two electrons have been placed on the first circle of the sixth group by cæsium and barium, the whole work of the rare earths,

from lanthanum (No. 57) to lutecium (No. 71) is devoted to filling the empty circles, and except for one electron placed by lanthanum on the fourth circle of the fifth group, all go to the fourth group which, at the end of

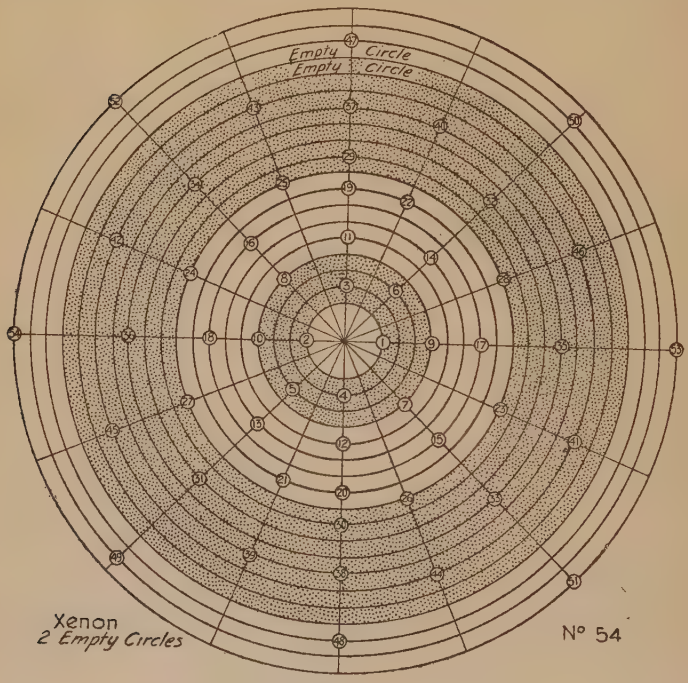


Diagram 15.

the rare earths period, holds 32 electrons in its various circles, and is quite full.

All this work having been done so far down in the substance of the atom, the surface has, of course, remained utterly unchanged, and the valency electrons

remain exactly of the same number as at the beginning of the series of rare earths, that is, they follow boron, aluminium and scandium and are all tri-valent or with three valency electrons (though two of them, Nos. 58 and 59 sometimes lose another electron and may become quadri-valent). All the rare earths have a close similarity of properties for the same reason. They possess some of the remarkable characteristics of the elements of the former interpolated numbers, due to causes connected with the incompleteness of the groups they are building.

At No. 72 the fifth group begins to be completed, and this is finally full at gold (No. 79), which places its final electron on the first circle of the sixth group and is in the same position as copper and silver, but is rather like copper than silver in being able to use two of the eighteen electron group behind it as valency electrons. This may seem curious since copper whose eighteen were insecurely bound owing to low nuclear charge could only use one, and silver none at all ; but opinions seem to be divided as to the cause, and some appear to think that copper and gold have *two* electrons on the outer group leaving the inner one still not quite full. However this may be, by the time niton, the last inert gas, is reached, all the inner circles are full and all the wounds healed, and the sixth group has three circles filled.

The last Period is incomplete, as we have seen, and contains only six members. All are radio-active to some extent. The elements of this Period increase their valency electrons by one with each succeeding member, as do the elements in the early Periods. It seems probable that the whole Period, if the members

had been stable enough to exist, would have consisted of eighteen elements and not of 32 like the sixth Period.

This completes our survey of the differing number of electrons available for combining with other atoms in the elements of the Periodic Table. The combining possibilities of each individual element depend on its own pattern, on its position in the general building, and on the way in which the work is proceeding at the time that the element in question comes to be built—whether the new part is going on steadily and straightforwardly or whether gaps are being left behind to be filled up later.

Some of the elements are " born lucky " and have no difficulty in attaining the stability they seek. Carbon with its four valency electrons and four places to fill in order to complete its octet, must find life very easy and " friendly." It has but to stretch its four hands and share all its four electrons with others, receiving by co-valency the share in four other electrons in return, and its task is done. It has no more " lone pairs " unshared to worry over, and things seem restful and easily adjusted. On the other hand boron with only three valency electrons is in a great difficulty. It would seem to be the simplest way for it to try to lose its three valency electrons and become positively ionised and go back to the pattern of helium. But boron has a constitutional difficulty in doing this ; its electrons are too firmly bound apparently, and the only plan is to try to complete the octet. But even if the boron atom shares every one of its three electrons, receiving three additional shares in return, it can only acquire six out of the desired eight. Its only plan is to

try to pick up an additional electron and become negatively ionised, and then it can share this stolen electron as well as its own legitimate three, and become " four-handed " like carbon.

In the next chapter we will study the 92 elements whose building we have watched and try to follow some of them in a few of their manifold combinations.

CHAPTER VII

STUDIES OF THE ELEMENTS

Synopsis of Contents: The world of the Inorganic and its simple combinations. No dividing line between it and the Organic ; only emergence. The chemical basis of life. Elements in the forefront of evolutionary movement. These four vital elements and two accessories. All belonging to earlier numbers in Periodic Table. *Hydrogen* described. Its use as a fundamental building-block. Its many combinations. *Carbon* and its vast number of compounds. Its place in the matrix from which life is believed to arise. *Oxygen* and its part in the building of life. Its " grasping " character. *Nitrogen*, inert chemically, but possessed of valuable stability. Sulphur and phosphorus as accessories. Reason for position of the four vital elements. Unenclosed condition of the hydrogen atom with no surrounding " shell " of electrons. Same characteristic in animal cell differentiating it from vegetable. Four vital elements all comparatively unenclosed and free. Examination of causes for special choice of the four amongst early elements in Periodic Table. Importance of power of combination. Double and triple bonds, and their influence in promoting combination of molecules. How the moving electrons of an atom can combine with other moving electrons. The electron-in-its-orbit as a " whole."

THE world of 92 elements at which we have arrived in our studies of the gradual building of things, is a very wonderful and interesting one. Here are 92 substances, each the result of a special building problem, each arising out of a balance of attractions, repulsions, magnetic forces (of which we have not spoken as yet), and influences of neighbouring elements and their pattern ; each with special powers of combination, or, as in the inert gases, with no such need ; each truly *individual* in a sense that the electrons and protons, of which it is built, could not be said to be.

These are the building materials prepared for the Life which is yet to come. In the stage of the world-building which we are now considering, there is no sign as yet of the Birth. We can hardly form a mental picture of that utter barrenness, with its waste of waters, naked volcanic rocks veined with minerals, steam and mingled gases, and simple combinations of the elements whose building we have followed.

With intention I say " simple " combinations because the processes of so-called " inorganic chemistry " are simple compared with those which arise when organic life has been put in charge. So striking is this difference that until comparatively recent times a line was drawn between Inorganic and Organic Chemistry, and it was thought that an entirely new vital force must account for the wonderful manner in which these same elements in definite proportions could be combined to form a vast variety of distinct substances.

Whilst in the inorganic, the combinations into which an element entered were usually few and quite simple, and the same number of atoms of two combining elements usually produced one substance and one only, in the chemistry of organic life a combination, for example, of 8 atoms of carbon, 12 of hydrogen and 4 of oxygen could be grouped into 66 different forms each representing a distinct substance.[1] This marvellous building out of the simple elements was thought to be due to an elusive something—a new vital force—introduced into " dead " matter, until our own chemists began to find the way to build up similar products and to imitate those which were built in natural laboratories of plant or animal tissue. Then when the numbers of

[1] Professor Julius B. Cohen, *Organic Chemistry*.

" organic substances," natural or artificial, had grown from the few hundreds at first recognised, to something approaching to a hundred thousand, it was seen that there is no real dividing line between the building in the inorganic and that in the organic world, there is only evolution, and an emergence of higher and more complex combination, as the living bricks are associated in groups which become ever more and more unlike that out of which they are built—even as the radium atom is unlike the simple helium and hydrogen nuclei out of which it is constructed.

Sir J. Arthur Thomson, in an article in *Discovery* for January, 1929, on the future of biology, writes in a striking way of the possibility of discovering a " chemical basis of species." " Every type," he says, " has its own protein ; there is a chemical accompaniment of individuality." He even believes that the solution of the problem as to the essential difference between male and female is likely to be found by the bio-chemist—the chemist of the organic.

Is this to degrade the building of life in its manifold forms and to break it up into its elements ? Sir Arthur Thomson does not write as if he thought so, for he speaks of " an increasing recognition of the mental aspect of living organisms, and of the need for synthesizing this fact " (that of chemical basis) " with that of psychical individuality."

Nothing, we are often taught, can be judged by its beginning, it is its *becoming* that shows its nature. What a wonderful living " dust " is that out of which Man and all living creation has been formed, and what greater glory could the Creative Spirit have had than to have endowed these living particles with a power to

become that which they were not singly, till through ever more marvellous combination, they should have produced a tabernacle for spirits akin to their Creator, with windows into the spiritual.

In this small book I do not propose to cross the threshold of Organic Chemistry. We are concerned with the preparation for the birth, and all lies still in the unborn state, instinct with the life of the Creative Spirit but not yet set free. Yet already the point where the growth is to appear, begins to push ; certain elements are made ready and are in the forefront of the vital evolutionary movement. Perhaps it would not yet have been obvious to any intelligence, if intelligence there had been to observe the situation, but so it was. Four elements are the really vital ones, and two others more or less accessories.

The first thing that will strike us is that they all belong to the earlier periods of the Table of Elements. Hydrogen is the very first of all, and the next three, carbon, oxygen and nitrogen, are in the centre of the second period, whilst the last two, sulphur and phosphorus (the accessories) are a little further on in the third period.

One might have thought that if so wonderful a thing were to emerge out of the barren elements as Life, with all its possibilities and apparently endless power of evolution, it would take its rise out of a combination of some of the later and more complex elements, where the dance of the multitude of electrons dazzles and confuses the senses and no human brain can pretend to follow or fully to grasp the pattern of things. But it is not so. The chosen ones are the comparatively simple members of the earlier Periods, and the special

four all lie actually within the first octave of the Periodic Table.

Hydrogen is almost ubiquitous both in organic and inorganic chemistry, nor is this to be wondered at when we remember that the hydrogen nucleus was at one time believed to be the sole building material used for the nuclei of all the atoms, and though now it is recognised that the helium nucleus with its four protons and two electrons is the main " block " used, yet we know that nuclei of pure hydrogen in company with some electrons enter into the building material of many of the elements, if not of all.

Hydrogen has normally but one valency electron (when negatively ionised it can acquire two), but it uses that " hand " all the time. It joins, of course, with oxygen in all substances that include water in their composition, and consequently is found in all living substance. In combination with carbon it is extremely active. Petroleum, for instance, and the various products of the natural oil wells are all composed of carbon and hydrogen in different proportions, and Professor Cohen gives a list of twenty or thirty different paraffins alone from which are obtained kerosene, lubricating oil, vaseline, paraffin wax and a number of other substances.

It does not appear to be clear as yet whether the origin of these oil wells is from inorganic or organic sources ; on the one hand it is possible that they arise under the action of steam out of the decomposition of volcanic rocks containing carbide of iron, from which paraffin is evolved, on the other hand they may take their rise from deposits of animal and vegetable remains which are to be found in their neighbourhood. On the

first supposition they belong to the stage of things which we are now considering and are an example of the early combinations of this element before life appeared. I am not proposing to enter here into the various inorganic substances which include hydrogen, but it will be recognised by everyone that their number is legion and that this gas is one of the most indispensable of the elements.

Carbon is so invariably present in all living substance and its products that the Science of Organic Chemistry has been described as that of the compounds of carbon. During the inorganic stage much of the carbon, which later was to be taken into the animal and vegetable organism, was in the atmosphere in the form of carbon dioxide, whose molecule is formed from one atom of carbon and two atoms of oxygen. We know already that carbon has four valency electrons and that oxygen requires two to complete its octet. This carbon dioxide with water and ammonia, when acted on by the ultra-violet rays of the sun form the very matrix from which life is believed to take its origin.

Oxygen, therefore, has its intimate part with hydrogen and carbon in the preparation for the first protoplasm. It has six valency electrons, and requiring two more, its two hands combine in countless ways with many other substances. It also accepts the hospitality of already "full houses" by co-ordinate links as we noticed in sulphuric acid. Professor G. N. Lewis makes the interesting remark regarding this element and fluorine that "they are the elements which show the strongest tendency to complete their octets and to obtain as nearly as possible the exclusive possession of the eight electrons. They therefore either take

electrons away from other atoms, forming ions, or they draw electron-pairs away from other atomic centres, possibly into a secondary valence shell," that is, I understand, they employ some of their deeper-lying electrons to form a further group into which they draw guests from other elements. A grasping character, perhaps, but full of individuality and of a sort of will to rule, if one may put it so. Mr. Haldane thinks that there was no pure oxygen in the primitive atmosphere. It would be found, of course, in the steam of volcanic processes and in water, in carbon dioxide, and in the " oxides " of many substances such as lead and copper.

Nitrogen is the fourth in this quartet. Unlike the other three it is said to be " very inert chemically," and " very little disposed to take on foreign electrons," so much so that it has even been compared to the " noble gases " and it certainly has a great stability of structure as is shown by the fact that it is evolved unchanged by certain disintegrating substances with which it has combined, having resisted the heat and other forces which have caused their disintegration. It has normally five valency electrons and places for three more to complete its octet, and the links which it does form with other atoms are characterised by unusual firmness. In fact its peculiar asset appears to be its stability of structure which to some extent affects the molecules of which it forms a part, rendering them more stable than they would otherwise be. It combines with oxygen to form the various oxides of nitrogen.

Sulphur with its six valency electrons, and *phosphorus* with five, cannot be said to be essential to all living substance, nor are they by any means invariably

present. We may regard them as accessories, and in a lesser degree other elements share with them in this position.

Perhaps we may come to see some reason for the special place of the four elements of life if we consider their structure more carefully. Hydrogen is the smallest and lightest of all atoms; it is also the *least enclosed in a shell.* Indeed when a hydrogen atom becomes positively ionised by losing its one electron it is a naked proton or unit of positive electrical charge. This renders it exceedingly motile, easily associated with quick changes and open to the call of other elements. Think of the position of a hydrogen ion. There is nothing to hamper it, nothing to hold it in or impede its freedom. It has a natural call for any free electron in a neighbouring atom and it is free to respond to the call of an atom requiring a proton. It has all the qualities of freedom and unimpeded movement which the rapid changes of a living organism requires.

When studying the very early forms of animal and vegetable life before their separation into the two great branches of evolution (as I did in a former book) one finds that the special point where the animal was differentiated from the vegetable and started on its higher evolution, was the fact of its remaining unenclosed by a shell or wall of cellulose. Whilst the vegetable secured itself from attack by a defensive thickening of the cell-wall, the animal remained open and unenclosed, free to receive every impression and exposed thereby to many dangers, but working its way at the very foremost point of evolution.

We may notice that in each case after hydrogen, up to the tenth element, neon, the *core* of the atom sur-

rounding the nucleus (that is the part of the atom which is stable and fixed, unavailable as a rule for combination by means of valency electrons) consists of but two electrons. In the more complex elements the core increases by the gradual addition of groups of electrons, and in the elements following neon it consists of ten electrons, that is to say an inner core of two, followed by a further shell of eight ; then after the inert gas argon there is a core of eighteen, that is an inner core of two and further shells of eight and eight respectively. After krypton there are 36 in the core (2, 8, 18, 8), after xenon 54 (2, 8, 18, 18, 8) and finally after niton, 86 electrons forming shells of 2, 8, 18, 32, 18 and 8. One cannot fail to be impressed by the increasingly enclosed condition of the nucleus which is the essential part of the atom, that which makes it what it is ; and one sees the immense advantage which the less hampered atoms of the earlier elements have when it comes to forming rapidly changing and yet stable combinations suitable for the matrix of the living organism.

This appears to limit the choice to the eight elements of the first two periods, for of course the inert gases helium and neon can have no part in this work, seeing that they have no power of combination. Is there any reason why carbon, nitrogen and oxygen should be chosen rather than lithium, beryllium, boron and fluorine ?

Studying the structure of the first three mentioned I think we can see facts which mark them as especially suitable for this purpose.

It seems essential that elements should not be chosen which by simple ionisation could take on the pattern of the inert gases and acquire a certain stability of

their own without combining with another element. Lithium and beryllium, by being positively ionised—by losing one or two electrons—could take on the form and pattern of helium, whilst fluorine, by becoming negatively ionised through acquiring an extra electron, could imitate the pattern of neon. It is true that in all these cases the positive or negative charge would be a call to an atom having the opposite sign, and so certain combinations would be effected, but compared with those possible to the elements in the middle of the Period, they would be few, first because they could only take place with elements having an opposite charge, and secondly because the number of valency electrons in the first two is so small, and the vacant place in the octet of fluorine is a single one.

On the other hand carbon is an ideal element for combination. Standing in the middle of the second Period it holds the balance of give and take precisely even, with its four valency electrons to offer and its four places in the octet to fill. It can, as we have seen, share one of its valency electrons with four other atoms, receiving in return from each a share in one of their electrons. The equivalent is perfect, and there are no valency electrons left unshared to raise difficult questions of co-ordinate links. It is no doubt this peculiar structure of carbon which has marked it out for an element of innumerable combinations, and one sees how specially fitted it is to forge the links of the living substance.

Boron may be considered unsuitable owing to its peculiar difficulty—mentioned above—in forming its octet, on account of having only three valency electrons to offer and five places to fill.

Nitrogen, the next chosen one, has five valency electrons and only three places to fill. Unless it shares by co-ordinate links it can have fewer combinations than carbon, for it has more to give than it can receive in exchange. However, its quality of stability seems to be a most valuable asset and the main requisite for a living organism is to possess essential stability with capacity for change in form.

Finally we come to oxygen. It is the last possible element of those with a core of two, and though it has only two places in its octet to fill and so would seem to be restricted in its combining power, we know from the remarks of Professor G. N. Lewis quoted above that it has a special tendency towards combination, (a striking contrast to nitrogen), that it forms co-ordinate links, and also accepts in certain cases unrequited gifts, and that it holds with a strong grasp that which it acquires, making itself as far as possible the possessive party in cases of shared electrons. Undoubtedly it is a strong element, fitted to impart individuality to the molecules which it helps to build.

These suggestions may afford some answer to the natural questioning as to why these particular elements should stand in the position they do in the evolutionary movement. Reason seems to mark them out as the most fitted for the work required. A still further light is thrown on the subject of their power of combination by some observations of Professor G. N. Lewis.

It may possibly have occurred to my readers that though it is easy to make a diagram of two chlorine atoms exchanging shares in their one valency electron, it would be impossible in this way to represent the union of two oxygen atoms, each with *two* electrons

to offer and to receive, because our picture of the atom with its octet seems only capable of touching at one face of the figure of eight. Yet oxygen does form molecules of two combining atoms, nitrogen with its three electrons does the same and carbon unites with carbon atom. These, Professor Lewis calls double and triple bonds, and he considers that they do create a sort of "strain" in the form of the atom (as it were pulling it to some extent out of its normal shape), and that the result of this "strain" is that they do not obtain quite the same balanced satisfaction through the completion of their octet in this fashion that they would do if they obtained it by sharing with other atoms. This unsatisfied condition affects the whole molecule and renders it less inert, more motile and ready for combination with other molecules in order to obtain a more complete satisfaction and balance by this means.

All this is rather theoretical, but whatever may be the exact state of a molecule whose atoms are united by double and triple bonds in this way, it seems to denote an increased desire for combination with other molecules, and what throws special light on the question we have been discussing is the fact that Professor Lewis is led to the conclusion that "the ability to form multiple bonds is almost entirely, if not entirely, confined to elements of the first period of eight, and especially to carbon, nitrogen, and oxygen."

He was led to this discovery by remarking the very great difference between substances in the second and third Period which were supposed to be analogous. He saw that fluorine and chlorine did resemble each other very closely, but oxygen and nitrogen were much further apart in character from sulphur and phosphorus ;

whilst carbon and silicon and their compounds, had still more remarkable differences. Eventually he came to the conclusion that the ability to form these multiple bonds in the case of the elements of the earlier period, were the cause of the difference, and, whatever it may mean ultimately, it marks off these three elements as distinct from others and as possessing certain powers of union with which the latter are not gifted.

When speaking just now of our " picture " of the combining atoms and the difficulty of visualising certain processes and conditions, it occurred to me that my readers may be brought up against a great difficulty when trying to imagine the union of electrons in two neighbouring atoms, if they remember that each of these electrons is ceaselessly rushing round its own nucleus and is never standing still for a moment.

I think the only way is to see the orbit of the electron as a whole, and the electron, which is passing round it at an enormous rate, as practically *in every part of its orbit all the time.* This seems at first a strange and untrue view, but as a matter of fact I think it fits in with the " discontinuousness " of all matter as we have learnt to know it. A piece of marble looks solid and smooth, but we know that it is composed of numbers and numbers of minute separate atoms which do not touch one another : water seems to pour continuously, but here again there are spaces between the atoms which compose it. Light seems to be shed on us in a continuous beam, but we have begun to believe in atoms of radiation and to realise that it is anything but the steady continuous wave which we thought it. It is not even found that the emission of the radiant particles is steady and constant—it appears that it comes in little

bursts, so to speak, and that there are spaces between these. Now I think an electron rushing around its orbit at an almost inconceivable rate is really equivalent to a vibration at all parts of the orbit, that is to little bursts of energy as it passes producing the effects of continuity, and thus it may be said to be one with its orbit and in this sense can be regarded as stationary. This is, I think, entirely in accordance with Shrödinger's new theory of the electron-in-its-orbit in which the electron itself disappears and nothing seems to remain but a series of waves persisting all round the orbit and forming a sort of electrical ring of vibration. One may visualise it by means of those tops provided with circular discs having patches of colour. A single dot of vivid colour becomes a ring when the top begins to spin.

However, there is another factor which we have not yet considered—that of magnetism—which gives reality and substance to this idea of the electron-in-its-orbit as an extended form of the electron. This we must consider in the next chapter.

CHAPTER VIII

MAGNETISM

Synopsis of Contents: Early views on electricity and magnetism. Later developments and theories. The electron-in-its-orbit an elementary magnet. Neutralisation of the resulting magnetic "moment" in two electrons revolving in opposite directions. "Dia magnetism" resulting. An illustration suggested. Neutralisation of the magnetic moment an important factor in stability. "Unsaturated" elements those with unneutralised magnetic moments. Pairs of electrons and the "rule of two," regarded by G. N. Lewis as even more fundamental than "rule of eight." Elements with odd numbers usually "paramagnetic," *i.e.*, having one or more moments of residual magnetism. Conjugation of "unsaturated" atoms to restore magnetic balance. Requirements for stability seen to be (1) symmetry of pattern, (2) electrical balance, (3) neutralisation of magnetic moment. Experiments by Stern and Gerlach to test magnetic moment of certain elements. Confirmation incidentally obtained of truth of Professor Bohr's value for magnetic moment, of his "quantum theory," and finally of the physical constitution of atoms as described in former chapters. "Pairing of electrons" and "conjugation" not to be taken as analogous to the pairing of male and female in organic or living substance.

THE relations of Magnetism and Electricity were not realised in ancient times and are only now being gradually unfolded in all their implications.

The phenomena of electrical attraction are said to have been first observed by Thales of Miletus (640–548 B.C.), and that of the magnetic attraction is mentioned by Lucretius, and is said to have been known by the Chinese a thousand years before Christ, when the lodestone seems to have been employed to guide them "across the trackless wastes of Tartary." Out of these two discoveries arose the sister sciences of Electrostatics

and Magnetostatics, that is the science of electricity at rest, and of magnetism at rest, and each was supposed to be entirely independent of the other and they were developed for a time independently.

Electrodynamics deals with the *motion* of electricity and magnetism, and as this science was developed, the relation between the two became evident. Professor Jeans[1] compares the three divisions of electro-magnetism to an arch of three stones. Electrostatics and magnetostatics form the two side stones, and electromagnetics rests on them and connects them. He says that "magnets in motion produce the same effects as electricity at rest, while electricity in motion produces the same effects as magnets at rest." It is considered probable that "all magnetic phenomena can be explained by the motion of these (electric) charges." "On this view the electricity and magnetism which at first sight appeared to exist independently in the universe, are resolved into electricity alone—electricity and magnetism become electricity at rest and electricity in motion."

Thus with our modern view of matter as consisting of particles of negative electricity and protons, and regarding electric currents as streams of electrons in motion, magnetism becomes a property of the motion of these electric currents, and we have to realise that the apparently quiescent magnet is full of "kinetic" (as distinguished from "potential") energy, and beneath its calm exterior is simply electricity in motion. "For," says Jeans, "two magnetic poles of opposite sign" (that is the north and south poles of a magnet) "attract, because two systems of current flowing in opposite direction attract."

[1] *The Mathematical Theory of Electricity and Magnetism*, J. H. Jeans, D.Sc., LL.D., F.R.S.

Every magnet, as we know, has a north and a south pole of equal strength. Perhaps I need hardly say that the end of the magnet which is usually marked " north " and which corresponds to the end of the compass-needle which points to the north, is really the south pole of the magnet, and turns to the north because it is attracted by the magnetic north pole of the earth. It is the north-seeking end. The magnetic lines of force run always from the north-seeking pole of the magnet to the south-seeking pole.

There is a difference between the magnetism of a magnet and the electricity of a charged body which we ought to observe. The magnet has two poles of opposite sign, which attract each other, and they seem in this respect analogous to positive and negative electricity ; yet they cannot be separated, as the positive may be separated from the negative electricity in matter. It is found by experiment (and can be explained by the molecular theory of magnetism) that if you cut a magnet in half the only result is to obtain two new magnets, with north and south poles as before. Therefore a body cannot be charged with magnetism of north or south polarity alone, in the way that it can be charged with positive or negative electricity. Each pole has a magnetic charge, but the whole body is in equilibrium. Thus a magnetic body or magnet carries " two equal and opposite charges at a certain distance apart," and the lines of magnetic force pass continually from the north-seeking pole, in curves outside the magnet, to the south-seeking pole, returning thence within the body of the magnet (thus forming a closed circuit) to their starting point.

Both in electricity and in magnetism the measure of

the force exerted between the poles of the one, or the oppositely electrified bodies of the other, depends on (1) the strength of each pole or of each electrified body ; (2) their distance apart ; and (3) the nature of the medium connecting them. In a line magnet, for instance, which is a line instead of a bar, having its poles at either end, the measure of such force—called the " moment " of its magnetism—is " the product of the numerical strength of either pole and the distance between the poles."

All this is preliminary to a slight study of the meaning and effect of magnetism in connection with the building of atoms and molecules, or the molecular theory of magnetism, a subject which is, I think, not yet very fully understood, though wonderfully illuminating and likely to become more so.

Borrowing from Professor Charles R. Gibson[1] let us make a very simple experiment which will help us to visualise what is beyond our powers of sight. Take an ordinary iron poker and wind round it, from one end to the other, a coil of insulated wire. As soon as we connect up the two ends of the wire to a battery and turn on the current, the poker will become a magnet and attract nails or bits of iron. As soon, however, as the wire is disconnected with the battery, the poker ceases to be a magnet. Here in Professor Jeans' words is " electricity in motion producing the same effects as magnets at rest." A magnet of this kind produced in " soft iron " is called an electro-magnet, and, by starting and stopping of the electric current, can be made to hold and to let go at will. Permanent magnets of hard steel can be made in the same way, and the

[1] *The Romance of Modern Electricity*, Professor Charles R. Gibson.

magnetism remains when the current in the wire is stopped.

Now supposing, instead of a piece of iron, surrounded by a coil of wire, we simply use a coil of copper wire of which the two ends are attached to a battery, and pass the electric current through it, strange to say this coil will itself become endowed with the properties of a magnet. Imagine this coil to be filled up inside its circular loop with some very thin material, and you would find the north pole of the magnet on one side of this circular "shield," and the south pole on the other. You could prove this by bringing the north pole end of an ordinary magnet to touch the coil of wire on the south pole side, when it would be attracted to it as to the south pole of another magnet; on the other hand this end of the ordinary magnet would be repelled by the north pole side of the coil as it would be by the north pole end of another ordinary magnet.

An electron-in-its-orbit, being a unit of electricity traversing a closed circuit, is necessarily an elementary magnet, having a definite measure or "moment" of magnetism. Since all matter is composed of protons and of electrons in motion around them, we might naturally suppose at first sight that all matter must be highly magnetic. But this could only be if the electrons were all revolving in the same direction. If, on the contrary, a pair of electrons are revolving in opposite directions, they will neutralise each other and there will be no magnetic moment at all. Two electrons, having the same moments and travelling thus around their nucleus from opposite points, being at equal distance from it but on slightly inclined planes so that their orbits were not identical, would have the north poles of

their respective orbits opposed to their respective south poles, owing to the different direction of their movement, and each would neutralise the moment of the other.

A simple illustration may make this clearer. Place your right hand, palm downwards, on the table with the thumb pressed towards the first finger and all fingers touching. It forms a rough oval and this may represent the path of the electron round its orbit. The magnetic poles will be situated at the root of the middle finger at the back of the hand and in the palm, and the magnetic lines of force will pass round the hand from north to south pole at *right angles* to the direction of the moving electron. If, to a tiny insect placed on the knuckle of your right hand, the electron would be passing round in a direction *contrary to that which the hands of a clock would take*, the knuckle at the back of your hand is the *north* magnetic pole, and lines are running out from it in both directions to the edges of the hand in curving loops which find their end in the south pole at the root of your middle finger in the palm. Now let a friend place his right hand beneath yours, the points of his fingers towards your wrist. This will represent the path of an electron travelling *in the opposite direction* round the same nucleus. Since this electron is travelling in a *clock-wise* circuit, the south pole will be uppermost and the magnetic lines of force will be running from the palm to the knuckles at the back of his hand, just the contrary to those in your hand. These two contrary magnetic currents will neutralise each other when the orbits are thus superimposed. This is merely a sort of picture intended to give a general idea of the situation. It is not to be taken as an exact model.

In by far the greater number of elements and compounds this neutralisation of the magnetic moments of the electrons in their orbits does take place, and the element or substance therefore has no magnetic moment and is called "diamagnetic." Hutchinson, in his *Intermediate Text Book of Magnetism and Electricity*, explains that according to the Molecular Theory of Magnetisation all molecules of iron or steel, whether magnetised or not, are complete natural magnets, having north and south poles. In their natural, unmagnetised condition they appear to arrange themselves in such figures or formations that their north and south poles respectively neutralise each other. In all kinds of elements we may remark that a complete circle of electrons round a nucleus, arranged in such a manner as to present the south pole of one magnet to the north pole of the other would have the result that each pair would be neutralised, and so long as there was not an odd electron, there would be no magnetic moment.

The process of magnetisation consists in turning the molecular magnets of the iron so as to bring all their north poles to point in one direction and their south poles in the other. The molecules now lie in lines along the bar which has become a magnet, and each will have a north pole—say to the right—and a south pole to the left. In the middle of the magnet the little magnetic molecules neutralise each other, since the north pole of the one is always applied to the south pole of the other, but at the end of the bar to the right all the north poles of the last molecules will be free, and on the left all the south poles of the last molecules will be free, consequently there will be a strong polarity or

magnetic force, at either end; north polarity on the right, south polarity on the left. This explanation makes it easy to understand why, if a magnet be broken in two, each part will be found to be a magnet. For, since it is impossible to cut through a molecule (the molecule being the least possible portion of an element which can exist as such, and consequently indivisible) the fracture must take place between them, and in this case a set of north poles will be left at one side of the break and of south poles at the other, and we shall have a magnet as before.

The neutralisation of the magnetic force is very closely connected with the stability of the atom or molecule of a compound, and an atom or molecule with electrons whose magnetic moment is unneutralised is always unstable and "unsatisfied," as we described the state of those whose electrical balance was uneven. The chemists use the word "unsaturated," and speak of a substance whose atoms or molecules are completely neutralised magnetically as a "saturated" compound.

Now it is obvious that if every electron-in-its-orbit (for remember, I am not speaking of electrons outside the atom) is an elementary magnet, and produces by its exceedingly rapid revolutions a definite amount of magnetic force, there must be in every completely saturated substance another electron having an opposite course to neutralise it; in other words there must be *pairs* of electrons with no odd ones.

Professor G. N. Lewis in *Valence and the Structure of Atoms and Molecules* (1923) lays very great stress on the "pairing" of electrons and thinks that the "rule of two" is even more fundamental than the "rule of

eight " or the octet. He points out the perfect stability of helium with two electrons which neutralise each other and produce this diamagnetic gas. And he shows that all atoms and molecules which have an odd number of electrons (so that all cannot pair) tend to be not diamagnetic but " paramagnetic," which is the opposite condition and means that there are one or more moments of magnetism left unneutralised.

The amount of a unit of this magnetic force has been calculated by various people and the result is called a " magneton." So we may say that an " odd molecule " or atom has so many magnetons of magnetism, and we know that it means that one or more of the little magnets has not paired.

Generally it will not have paired because it has none to pair with, but strange to say, in some cases it appears that the pairing does not take place in spite of an even number of electrons being present. This appears to be the case in oxygen for instance, and the " paramagnetism " of this element is a constant puzzle to physicists. But oxygen appears to be in many ways an unusual element, and this failure to pair *may* be due to the double bonds of which we have spoken, which seem to cause a strain in the pattern of the atom, so that the resulting electrical satisfaction is not complete. Yet carbon and nitrogen which also form double or triple bonds are not affected in this way. The whole subject of the magnetic condition of elements is complicated and not fully understood, but it is clear that both in the atoms themselves and in the molecules formed by the combination of atoms, the pairing of electrons is a very fundamental phenomenon.

When two " unsatisfied " or " unsaturated " atoms

are joined together and their unpaired electrons form a bond, Lewis called this a conjugation.

Chlorine in its single atom is unsatisfied, having an unpaired electron ; so is hydrogen and so are all the " halogens " (see Table of Elements). But by combining in two atoms so that the unpaired electrons find a partner, the magnetic balance is restored and there is a diamagnetic result. This is conjugation. (Notwithstanding it must be remarked that the union between two negative, or electron-seeking, elements like chlorine or fluorine is not a very strong one and may be broken when a firmer bond offers, by a new conjugation of electrons).

In the same way two atoms which have formed a double bond and are not entirely " satisfied " may conjugate to reduce the " residual magnetic field " and produce a diamagnetic substance. Thus oxygen, though in its double atomic form paramagnetic, as we have seen, must be satisfied when combined in organic compounds, since these are practically always diamagnetic. Therefore we must presume that its strangely unpaired electrons must conjugate with those in the combining elements.

It seems as if the symmetry of the " pattern " in elements was important and affected the power of pairing in the electrons composing it, and for perfect stability and satisfaction an element should have (1) symmetry of pattern, (2) electrical balance, (3) neutralisation of magnetic moment by the pairing of electrons. All these requirements are met in each of the inert gases ; hence their great stability.

When atoms become ionised (by taking up or losing electrons) and thereby take the pattern of the nearest

inert gas, they acquire symmetry of pattern and probably neutralisation of magnetic moment, but the electrical balance is upset, and therefore, though they have considerable stability, they are not completely satisfied and still go seeking for other electrons or protons to restore the latter condition. One begins to see the many causes of dissatisfaction and discontent in an atom, and one realises that each one has its individual life problem to be solved.

Very interesting experiments have been made by Stern and Gerlach with regard to the magnetic condition of various elements, and these, besides the information they give as to the elements in question, have proved the correctness of the calculations made as to the unit of magnetic force, or magneton, and have also supported the theory as to the emission of radiant energy in " little bursts," as I expressed it just now in speaking of the electron-in-its-orbit. This is called the quantum theory and is very far-reaching and has many applications in all departments of physical phenomena. The main idea seems to be that nothing happens gradually like a wheel moving up or down an inclined plane, but always in little steps, so that all changes, whether in the magnetism or energy or position of an electron, have to take place in this manner, and at a given moment an atom will be in a definite condition and not half and half, so to speak. This fits in with the atomic theory of matter and electricity and radiation and magnetism, none of which are regarded as *continuous*, but all in separate particles or atoms, so that it has been suggested that in the future it will come to be recognised that not on *measure* but on *numbers* is the world built.

The experiments made by Stern and Gerlach were in something after this fashion : They passed a stream of the vapour of the element they were experimenting on through a tiny hole and directed it between the poles of a powerful electro-magnet. They exhausted the air and they so reduced the temperature that the atoms were not flying violently about and hitting one another, but were proceeding more quietly along the track. Now when they got between the poles of the magnet, if the atoms were themselves little magnets with their electrons unneutralised, they would be attracted to one or other pole of the magnet according to their own magnetic polarity, but if they were neutral atoms they would keep straight on.

When the experiment was made with silver it was found that the tiny stream of atoms divided into two parts and half went straight on whilst the other half were deflected towards one of the magnetic poles. None of the atoms were in any intermediate position, one notices ; they were in one state or the other. Their behaviour was understood to prove that silver had a magnetic moment and was not entirely neutralised. The experimenters were able to calculate the amount of this moment, and found it almost exactly equal to that which Professor Bohr had arrived at as the value of the unit of magnetic force, or the magneton. So they knew that silver had a moment of one magneton.

Now silver is like sodium and potassium, and also like copper and gold in having one electron by itself on a new circle. The numbers of electrons already placed are even numbers, and this is the odd one which therefore cannot be paired. Evi-

dently this electron is responsible for the single magneton which is found unneutralised in all these substances.

When we speak of the " pairing of electrons " in magnetic satisfaction or saturation so as to establish a balanced magnetic condition, we must realise that it is not an electrical balance that is attained; the electrons are, of course, both particles of negative electricity and would normally repel one another, but owing to their magnetic properties it comes about that two electrons whose orbits are running in opposite directions will behave like two magnets placed end to end with the south pole of one close to the north pole of the other, and will attract one another and neutralise each other's magnetic moment.

In spite of the word " conjugation " employed by G. N. Lewis, which inevitably reminds us of the conjugation of water weeds in the plant world for reproductive purposes, I think we must not associate this pairing of electrons with any hint of the eventual pairing of two living principles in Nature. I have two reasons for thinking thus. In the first place there are already in existence two opposite principles (positive and negative electric particles) which play a definite part together, and if the first foreshadowing of " maleness " and " femaleness " is to be found at all in the inorganic, it is surely here that we must seek it. Secondly, in the conjugation of water weeds, the two cells which appear exactly alike and cannot be distinguished in appearance, do not behave alike, for upon coming together, the dividing wall generally dissolves and *the one cell passes over into the other*, completely fusing with it, so that the two are one. No hint of such

a difference of function is to be gathered from the behaviour of the two electrons, and the word "conjugation" must not, I think, be taken in such a sense. In the last chapter, when speaking of the nucleus, I shall say what more I have to add on this subject.

CHAPTER IX

THE INERT GASES

Synopsis of Contents: Apparently anomalous position of these "noble gases" in the spiral of evolution. Seemingly a full stop. Their existence nevertheless foreseen as a necessary completion of the Periodic Table. These gases seen to be the completion of a cycle or rhythm in the spiral: the moment of rest between one rhythmic movement and the next. Degrees of perfection, from simple perfection of helium to more complex neon, argon, krypton, etc. Discovery and nature of the "noble gases." First five all in the atmosphere. Argon in largest quantity but in combination with the other four. Discovery of helium in the sun. Discovery of argon and of helium (in the atmosphere of earth) and eventually by "fractional distillation" of the other three gases, neon, krypton and xenon. Niton, a product of radio-activity discovered a few years later. Story of the discovery of first five as told by Professor M. W. Travers. Distribution of these gases in the world and universe. Reason for their "rarity." Some of their qualities and the situations in which they are found. Always uncombined or "inert," not excepting xenon with its unfilled circles. Niton's short life. Its descent from radium which is descended from uranium with a life-time of millions of years.

AMONGST all the elements which we have been considering there is one group which inevitably attracts our attention by its curious aloofness from all the rest. The self-sufficiency of the "noble gases" and their perfection of electrical and magnetic balance and of pattern raise questions in our mind which are not easy to answer. Other things in Nature all seem to be moving on in the great spiral of evolution; they manifest their incompleteness by their tendency to combine, their openness to their surroundings; these, on the other hand, mutely assert their independence, and their

sign appears to be a circle rather than an open spiral. At first sight they are even irritating to our thought, and are like full stops in the middle of a sentence where we expect a comma.

Whether our questions and feelings of disturbance can be completely settled may be doubtful, but a closer study will do something to bring us into touch with their special place and meaning.

That they have a special place is proved by the fact that in the Periodic Table of atomic numbers gaps were awaiting their discovery for a quarter of a century at least. Julius Thomsen, writing in 1895 when argon and helium had just been discovered but none of the other inert gases as yet, appears to have realised that this group of elements must exist, and to have predicted the discovery of such a group having weights extraordinarily near to the actual weights of the inert gases.

What led him to this prediction? It is evident, I think, that in studying the *rhythms* of the Periodic Table he found a gap at the end of each wave or rhythm where the period of peace should be, before the start of a new rhythm. Follow the course of one Period and my meaning will be clear. Beginning with the so-called "electro-positive" element lithium, where the tendency is to part with the superfluous electron, we pass on through beryllium and boron having still the same tendency, to carbon where we reach a sort of equilibrium, it being now indifferent whether the element loses or gains four electrons, since either way it attains stability. Here is the halfway point between one complete pattern and another. This is the height of the wave. Onward we pass to the elements requiring more electrons to complete their octet; the so-called "electro-negative"

ones, till finally we come to fluorine, needing only one more electron to reach the perfect pattern of neon. We have passed from the " plus " elements, through the elements in equilibrium in the centre of the rhythmic wave, to the " minus " elements at its close, and it seems obvious that the tranquil moment of peace and perfection must be represented in the next element before we start again with a " plus " element beginning a new wave. So we must look at these gases as the transition elements, the moments of pause and stillness between two rhythms, a rest like that of the heart between the systole or contraction and diastole or dilation of its rhythmic movement. This is the zero, where there is neither plus nor minus, and one realises that it is as much a necessity in the constitution of things as is the movement which precedes and follows it.

Clearly we must not regard it as a circle ending all, but as the completion of a cycle in the spiral of evolution, whence once more the new rhythm starts in vertical line with the first element in the last cycle. This puts a new complexion on the problem and certainly gives meaning to the group we are discussing and shows their place in the constitution of things. It also impresses on us the rhythmic nature of the building of the Life-Force, which I think is important, as it seems to be a far-reaching principle. No one can be blind to it, for it is written large, it is written small, and in all the manifestations of Nature it is perhaps the most unescapable of phenomena.

So the inert gases are not a " portent " or in any way " out of the picture," but are to be regarded as degrees of perfection out of which and towards which the elements are growing. There is the simple perfection

of helium and there is the more complex perfection of neon ; again there is the still higher perfection of argon, with the further developments of krypton, xenon and niton. There is no full stop. It is but the end of one cycle which prepares for the next.

The story of these noble gases, the manner of their discovery, their nature and constitution, and their distribution in the universe, are all most interesting and worth our study.

The first five are all contained in the atmosphere, and unknowingly we breathe them every moment of our lives. When, by chemical means, the oxygen and nitrogen of the ordinary air have been removed, there remains a small residuum of a gas heavier than the nitrogen and so closely associated with it, that it has to be separated by special chemical means. This is argon, and it constitutes about one per cent., or rather less, of the atmosphere. The quantity varies to some extent according to the quality of the air, the height at which the specimen is taken and so on, but roughly speaking it is between 0·99 and 1 per cent. of the whole. This argon, however, has been found not to be pure, but to contain within it minute quantities of the first five inert gases (including pure argon) in about the following proportions :

Helium 0·055 ; neon 0·16 ; argon (pure) 99·785 ; krypton 0·0005 ; xenon 0·00006.

Colourless, odourless, tasteless and inert (that is, incapable of combination), hidden within the recesses of the nitrogen of the atmosphere in these minute quantities, what wonder that they escaped detection even after their place was known and awaited them in the Periodic Table of atomic numbers.

Helium, which took its name from the Greek word for the sun, was discovered by means of the spectroscope, as existing in that orb, as early as 1868, but it was not until after the discovery of argon (name from the Greek signifying "inactive"), that it was found to be present in the atmosphere of this earth.

The manner in which argon was discovered is interesting. It was noticed that the nitrogen obtained from the atmosphere was distinctly heavier than that which was got from other sources (by about 1/120th of the whole weight), and so it appeared that some heavier gas must be associated with the nitrogen. Eventually the experimenters succeeded in absorbing, under suitable arrangements, the oxygen and hydrogen of a specimen of common air by passing it over red-hot copper, and the nitrogen by means of hot magnesium or lithium, and a residuum was left of a heavier, unknown gas. This was argon. Its discovery in the atmosphere set everyone searching for the new element in other associations, and eventually Sir William Ramsay discovered it in mineral compounds mixed—but not combined—with hydrogen and another gas, which proved to be the element hitherto only known as existing in the sun, which they had called helium.

Now new doors began to open and some of the physicists saw a new light. Julius Thomsen (as well as Sir William Ramsay and others) made his prediction of the group which must exist and should fill the vacant places in the Table of atomic numbers. Search for these became vigorous, and the new element, argon, was, for various reasons suspected of hiding another gas, as nitrogen had enfolded the argon itself till separated by the means described.

The means adopted for the thorough analysis of argon was that called fractional distilling. Every gas is, of course, capable of being reduced to a liquid if a sufficient degree of cold is applied, though this degree will vary with the particular gas. By means of the intense cold of liquid air, the argon was first liquefied ; then the temperature was gradually allowed to rise till it began to boil.

As different gases have different liquefying points and freezing points, so they have different boiling points. In the case of the inert gases of which we are speaking the boiling point is extremely low. I will give these in their order (though the estimations of different chemists vary slightly) and I include niton, though it does not concern us here.

Niton—62° (minus sixty-two centigrade, that is, its boiling point is 62 degrees centigrade below the freezing point of water). Xenon—109°·1, krypton—151·7 (some chemists say—101°) ; argon—186·1 ; neon—245·92 ; helium—268·7.[1]

It will follow from these figures that the first to boil if all these gases (not including niton) were mixed would be helium, at the extraordinarily low temperature of 268 degrees below zero centigrade. If at this point the vapour could be caught before the other elements began to boil a tolerably pure specimen of helium would be obtained. Neon would be the next to boil and could be caught and distilled in the same way ; then argon, and finally krypton and xenon. Of course the experimenters did not know what they were going to find, but by this kind of procedure they did actually very quickly discover neon, a lighter gas than argon,

[1] *Text Book of Inorganic Chemistry*, edited by Dr. J. N. Friend.

which filled the empty place between fluorine and sodium, and soon afterwards the two heavier gases, krypton, filling the place between bromine and rubidium and xenon, fitting in between iodine and cæsium.

These gases were discovered about a year before the great bomb of discovery of radio-activity which shook all the scientific world to its foundations. But niton, the product of the disintegration of radium, was not discovered till a few years later, when it was realised that the helium found in minerals—often in association with argon—was the other part of that same disintegration of the radium atom, being the particle shot forth out of the atom which left behind it the new element niton.

The story of the discovery of these first five inert gases of the atmosphere is told at length by Professor M. W. Travers in *The Discovery of the Rare Gases* (1928), and it gives a vivid picture of the hard, patient work, the disappointment—almost to the point of despair—the indomitable perseverance and the thrills of the final reward, which mark the track of such adventures. The whole research, from the beginning of the investigation in 1894, occupied six years and a half. Professor Travers was associated with Sir William Ramsay (then Professor Ramsay) in the work, and they carried through this great exploring adventure together, sharing its struggles and almost insuperable difficulties, its disappointments, and final glorious success. Others were following the same trail and at times it was a race between the various adventurers for the goal. But one seems to feel that it was at bottom the *Truth* that mattered to them, and not only which should reach it first.

It began, as I have already explained, by the discovery of a difference in the nitrogen obtained from the air and that obtained from other sources, which led to investigations resulting in the discovery of argon—a heavier gas—associated with the nitrogen of the atmosphere. This was in the summer of 1894, and in the autumn of that year Professor Travers joined Ramsay with the purpose of examining this new gas, fixing its chemical properties, and any physical properties which should explain its nature, deciding whether it must be regarded as an element, compound or mixture, and if an element, finding its atomic weight and fixing its position in the Periodic Table.

As the research went on they came to the conclusion that if a mixture, it must be a mixture of *inert* constituents ; if a compound it must be a very stable one, as they could not produce any chemical change by any means known to them.

At one period it was thought that it might prove to be a mixture of three gases all of which possessed nearly the same atomic weight. This idea was mentioned at the Meeting of the Royal Society at Toronto in 1897, and the names suggested for the supposed trilogy were Anglium, Scottium and Hiburnium. However, as we know, they had not yet arrived at the true solution of their problem.

Ramsay was a great believer in the Periodic Table, and felt convinced that the empty places at 2, 10, 18, 36 and 54 were about to be filled by a group of inert gases.

Meanwhile helium, which had long since been known to exist in the sun, had in 1895 been discovered to exist in minerals on the earth. Being a product of the

disintegration of radium and uranium, it would naturally be found associated with these in the rocks containing them ; and in working upon this gas and argon which together with hydrogen was now found associated with it in minerals, Ramsay and Travers came to the important conclusions that both argon and helium were mon-atomic (that is they existed in single atom molecules, not in two atoms forming a molecule), that the weight of helium was very close to four and that of argon very close to forty, and in fact that they fell into two of the vacant places in the Periodic Table, but still leaving vacant the places for the remaining three elements of the expected group of inert gases.

Argon's position in the Periodic Table was still a matter of much discussion owing to the fact that potassium was heavier than it, and yet there was no question, on the ground of periodic grouping, that argon must come first ; and thus it was finally placed.

Though still believed to be a pure element, the possibility was now recognised that a small quantity of other gases might be associated with it, hiding beneath it as did argon itself behind the nitrogen of the atmosphere, and that these might be one or more of the missing elements. Good reasons were advanced by physicists why these elements should be found in the atmosphere. It must be remembered that so far helium, though detected in the sun, and found in minerals of the earth, had not been discovered in the air.

These ideas were worked at unremittingly. The spectrum of helium showed certain lines which were coincident with those of argon (in the state in which they knew it), and they could not account for these.

Surely the solution must be, they argued (correctly enough, as we now know) that argon contained some helium associated with it. The investigations now proceeded on the assumption that the missing gases must be present, in very small quantities, mixed with argon and helium. They were hot on the trail, but the problem of how to separate them seemed insoluble.

By the end of 1897 they appeared to have exhausted all other possible sources of the unknown gases. Ramsay still had faith in the Periodic Law. They determined to work on argon by fractional distillation of which process I have given a slight outline above. For this purpose, however, liquid air was required in order to reduce the temperature of argon to a liquid state in which it could be boiled for distillation. At that time the supply of liquid air was very limited. About a litre, or rather less, was brought to the college by Dr. W. Hampson, inventor of a simple process for liquefying it, and the work of investigation proceeded with fresh ardour. They relied on the spectroscope for diagnosis of any discovery that might result.

On May 31st, 1898, after fractional distillation of a sample of argon, a small quantity remained in the tube ; evidently something different from argon, which did not boil at the same temperature. Of this a tiny amount was introduced into an exhausted Plücker tube, the terminals were connected with the induction coil, current turned on, and each of the observers picked up a spectroscope. At once it was seen that the spectrum was different from that of argon or of helium ; *a new gas !*

One imagines the thrill of that first sight of one of the long-sought elements. Yet not the one for which

they had been seeking (No. 10 in the Periodic Table), for it was not likely that this lighter gas would be found in the *less* volatile fraction of argon. Obviously it was one of the heavier members of the series. Before night krypton was diagnosed, its atomic weight calculated as about 80, and its place in the Periodic Table fixed between bromine and rubidium.

At a meeting of the Royal Society on June 9th, when a paper was communicated with the announcement of the discovery, a hint was given that Ramsay and Travers were on the track of another *lighter than nitrogen* gas, and hoped soon to discover if it existed. Another physicist made a statement of the same description, and there was doubtless some degree of rivalry, the other man having the advantage of being able to obtain any quantity he required of liquid air, since he had a secret means of manufacturing and was well versed in low temperature research. However, with the help of Dr. Hampson, Ramsay and Travers had the joy within three days of tracking down the hidden one.

On June 12th the most volatile fraction of the argon distillations was examined by the spectroscope in the usual way. " But this time," writes Professor Travers, " we had no need to use the prism to decide whether or not we were dealing with a new gas. The blaze of crimson light from the tube told its own story, and it was a sight to dwell upon and never to forget. It was worth the struggle of the previous two years, and all the difficulties yet to be overcome before the research was finished. The undiscovered gas had come to light in a manner which was no less than dramatic. For the moment the actual spectrum of the gas did not matter

in the least, for nothing in the world gave a glow such as we had seen."

The spectrum was afterwards carefully examined and compared with others; the atomic weight calculated and found to be 20 as expected, and here was neon—christened by Ramsay's son Willie, age 13. He suggested at first "novum," but his father thought "neon"—the Greek form would sound better. The event was communicated to the Royal Society in a paper read by Ramsay on June 16th, and the defeated competitor in the race for discovery warmly congratulated the discoverers.

It was now found that neon, besides having some argon with it, was also mixed with helium. In order to separate these by distillation a lower temperature than that of even liquid air was necessary, and eventually it was seen that only by means of the intense cold of liquid hydrogen might such a temperature be obtained.

Meanwhile the research proceeded in an effort to separate the argon-krypton and argon-neon mixtures and to obtain all these gases in pure form. By means of liquid air the former mixture was liquefied and fractionally distilled in order to separate its constituent elements. There were many difficulties and puzzling circumstances.

One evening, at the end of the fractional distillation of these argon-krypton residues, a small bubble of gas remained behind, non-volatile at the temperature of liquid air, and therefore evidently dissimilar from argon and krypton, which had boiled and distilled away. This was carefully collected and examined in a vacuum tube. A most striking feature was the beautiful blue

glow from the tube. Its spectrum, compared with argon and the other gases, showed that it was clearly a new discovery, and they at once guessed that it might be the fifth member of the group of inert gases, and that its place would be found between iodine and cæsium. It was long, however, before they could collect enough of this rare, new gas to substantiate their supposition. The gas was named xenon, "the stranger," and the discovery was announced at the meeting of the British Association at Bristol in September, 1898.

The observers were terribly hampered by the want of a liquid air plant, and it was not until, eventually, funds were provided for procuring this, that they could do satisfactory and accurate work. Eventually, after much patient and arduous labour, they determined the atomic weight of krypton and xenon (depending on their density) with sufficient accuracy to fix their position in the Periodic Table, the former being calculated at 81·5 and the latter at 128.

The last stage of proceedings began in 1899. It concerned the study of the lighter gases, and as the heavier gases had been condensed and fractionally distilled by means of liquid air, it was now found necessary, in order to do the same with neon and helium, to obtain a lower temperature. Liquid hydrogen would provide this. Travers was entrusted with the designing and making of an apparatus for the manufacture of liquid hydrogen, and his friends in the laboratory predicted that if he succeeded, he would blow himself up. It was far from unlikely! In his first attempt, with a patchwork machine, no one—even had there been space in the compressor-room when the plant was working—would have felt inclined, he says,

to adventure himself there, and Travers worked alone. Their attempts to liquefy hydrogen with this machine failed. But it had become clear to them that to succeed in so doing was the only way to carry on their researches with the lighter gases, and the failure only spurred Travers on to the great undertaking of making the whole plant with his own hands. He says he does not think the liquefier cost more than £5. It was frequently used on subsequent occasions, and when he left University College it was deposited in the museum of the Chemistry Department.

On June 30th, 1899, the machine was tried, but broke down. On July 7th it was tried again, after an overhaul, started well, and liquid hydrogen began to trickle, but immediately there was a block. Pressure went up at once, and there was a choice of holding on with the imminent risk of being blown up, in the hope that the pressure would blow out the substance blocking the valve, or of by-passing the gas from the compressor and letting the apparatus warm up again, thus setting free the valve, when, of course, he must begin all over again. He had very little liquid air at the moment, and this was a necessity for a fresh trial, so he held on. The pressure went up and up! Ramsay, at his shoulder, protested, but in vain. Just as the pressure was reaching a limit beyond which he felt that it would be madness to go, he did something to the valve—apparently by accident—which had the effect of freeing it. There was a loud hiss, and hydrogen was seen to fill the upper vessel and presently to run into the lower one, which filled in a minute or two.

By dint of determination in the face of thrills of such nerve-racking quality as the above, and after "a

nightmare of a month's duration," as he expresses it, the difficulties were overcome and the means obtained for the work on the lighter gases. The want of money seems to have hampered them all through, and especially in procuring or making these most necessary plants.

The day which saw the first successful liquefaction of hydrogen, ended with the successful purification of neon. Travers says: "I do not think we spoke more than an occasional word or two till the tube containing the precious sample of gas, all the pure neon which was likely to be available for years to come, measuring some 15 c.c.s, was standing safely in the tube-rack." It was a thrilling day, but a most exhausting one.

The value assigned to the gas previously of approximately 20 in atomic weight was confirmed within the limits of experimental error. This concluded the investigation, which had begun with the discovery of argon, and led on to that of helium, krypton, neon and xenon in this order.

This short résumé of a most dramatic episode in physical exploring, has seemed to me worth including here, not only on account of its intrinsic interest, but also because of the light it throws on the strenuous nature of the work which is being done by these adventurers, the actual risk to life cheerfully undertaken, and the spirit of comradeship and of devotion to Truth which marks the men who are seeking it in Nature.

Taking these six inert gases in the order in which they come in the Table of Atomic Numbers, we may note some interesting points with regard to the distribution of each. Helium is found in all sorts of associations, though never in combination. When we remember that all the elements are believed to be

mainly built out of helium " blocks " and that radio-active substances as we have just said, emit pure helium, uncombined and unaffected by its long association within the prison of the atom of the radio-active substance, we shall not be surprised to find this strangely self-contained and isolated gas to be almost ubiquitous. It is found in the air though in exceedingly minute quantities ; it is found in sea and river water and in the gases from mineral springs. It is contained in the older rocks and minerals, where it is probably the direct result of radio-active emission. One may ask how it is held within the substance of the mineral, seeing that it is a gas and not combined. It is found that in order to liberate it, the mineral must be powdered to extraordinary fineness and heated with nitric acid in an exhausted tube, and the conclusion reached is that the helium is contained in minute cavities which " though invisible under the microscope " are " large compared with the molecular structure." (J. N. Friend, *Text Book of Inorganic Chemistry*.) It is thought that the pressure of the gas in these cavities must be very great. It is urgent to be released.

Why is it that whilst helium is constantly being expelled by radio-active substances its quantity is so small in relation to that of other elements ? The rarity of helium and of the inert gases is considered to be due partly to their inactivity, since in the first place, during the formation of a solar system the atoms which were not attracted to form chemical combinations with other atoms would simply rebound and fly off when colliding with these. This is the view of F. W. Aston, and he says these inert gases would tend to gravitate towards the larger masses, such as our sun.

But, in the second place, the want of power to combine would leave these gases with a liability—even when evolved upon this earth—to fly off into space. G. J. Stoney says that solid globes hold an atmosphere by their gravity, the strength of which determines the composition of the atmosphere. Were it not for gravitation the particles of the atoms of a gas would fly off into space. He thinks this accounts for the moon's airless condition. At a certain rate of velocity (seven miles a second) molecules of hydrogen and helium tend, he says, to fly off from this earth into space and be lost, and this to some extent is believed actually to occur, but hydrogen is safeguarded by its great power of combining with other elements, and by this means is far more frequently retained (J. W. Mellor, *Treatise on Inorganic Chemistry*.)

Helium is said to form a considerable part of the sun's atmosphere and to be the principal constituent of the hottest stars. At 50 miles above the surface of the earth there is believed to be twice as much helium as oxygen; "at 100 miles the atmosphere is mainly helium and hydrogen, and at 500 miles these two gases are the only ones to be found." (*Chemistry of the Rarer Elements*. Professor B. Smith Hopkins.) This fact throws a most interesting light on the use of hydrogen and helium nuclei as the main building blocks of all elements. Here in inter-stellar space are the bricks of the universe scattered in infinite number, and here those set free by disintegration of matter tend to return, but whether to be once more welded into higher elements no one can say.

Helium has been employed in aeronautics to a considerable extent, its great value consisting in its being

a non-inflammable gas lighter than air. Towards the end of the War a great demand arose for it to fill observation balloons. A natural supply had been discovered before this in Texas, associated with other gas, and Government plants were rapidly established to collect and purify the helium. Although the special need for the purpose of balloons came to an end, with the signing of the Armistice, before any great quantity had been shipped, the industry continued, as the value of the gas in Aeronautics was realised. Its costliness was found a difficulty, and instead of merely letting it escape when an airship or balloon wished to descend, as can be done with the cheaper hydrogen, it was necessary to compress it into cylinders to be purified and used again. Sometimes it has been used mixed with hydrogen in such proportion as to avoid the danger of explosion, hydrogen being both lighter and cheaper.

Helium is much used in scientific study in connection with radio-activity and in work requiring very low temperatures. The boiling point of helium is the lowest of all known substances. For very long it resisted all efforts to liquefy it, but now it has been not only liquefied but quite recently has actually been solidified or "frozen."

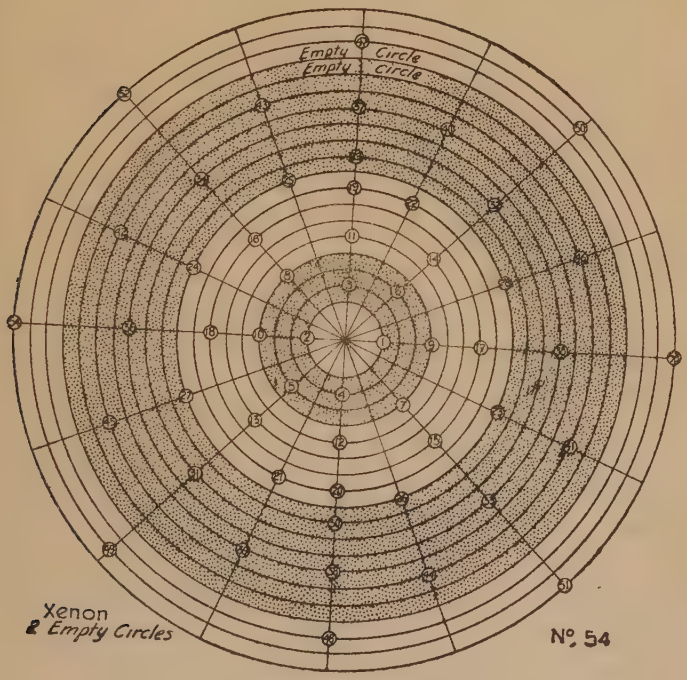
Neon (from the Greek meaning "new") is the next in order of the inert gases. It also exists both in the atmosphere and in mineral spring water. As with the other inert gases, many attempts have been made to induce it to combine with other elements, but there is no confirmation of any success.

Argon, the next in order, is found in far larger proportions than the other gases of this group. A definite amount of argon is found to be present in the atmosphere

at all heights (up to some miles) and in varying conditions. Over the open sea slightly higher quantities have been found. From the air it finds its way into sea and river water and is present in the gases of many natural springs. It is more easily dissolved in water than the atmospheric nitrogen with which it is associated, and so the curious fact is accounted for that there is more argon in the air-bladders of fish than in the ordinary air, and the deeper the water in which the fish live, the greater the amount of argon. Dr. J. N. Friend tells us that " it has been found free in plants and occurs in the blood of animals, but not in combination," and Dr. J. W. Mellor says that argon found in the blood of animals and in the roots of certain plants is not combined with any other constituent of the blood or sap, but remains free and has no special effect save as diluting these. It is not altered in its proportion to nitrogen by being breathed by animals even when the composition of the air has been greatly altered. Truly a strangely impassive and unchanging entity! Dr. J. N. Friend remarks that " it appears to be generally assumed that atmospheric argon has existed in the elementary state since the earliest stages of the world's history "—a long record of changelessness!

Krypton (Greek " the hidden one "), is found associated with argon in the atmosphere as we have seen. This is the only source whence it has been obtained, though by means of the spectroscope it has been detected in the gases of mineral springs. It is supposed that the aurora borealis is due, at least in part, to the presence of krypton in the atmosphere, since the spectrum of these " Northern Lights " has a number of strong lines corresponding exactly with those of krypton.

Xenon (Greek " the stranger ") was found about the same time as krypton. The quantity existing in association with argon and the inert gases already mentioned is exceedingly small, not more than six



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hundred thousandths per cent., and it seems amazing that so inconceivably minute a quantity can be measured and manipulated in experiment. Yet, as we have seen, it has been isolated, its boiling point ascertained, and endeavours made to induce it to com-

bine with other substances, but without satisfactory result. Of all the inert gases one might imagine that this would be the one most likely to form combinations, on account of the constitution of its atom with two unfilled circles behind the last eight electrons.

This is the only inert gas with unfilled circles in its composition, and one would suppose that some instability would result, and that there might be a tendency for some of the final eight electrons to be drawn inwards to fill the "wound" beneath, in which case the remainder would presumably become valency electrons and ready to combine. However this appears not to happen.

Niton or radium emanation (named by its discoverers in 1900, who at one time proposed to call it ex-radio), is the last of the group of inert gases, and already in this element instability has manifested itself to a degree which makes it clear that more complex forms will have little chance of surviving. Its own "lifetime" is very short: in three to four days half its amount will disintegrate and be resolved into α-particles, or helium nuclei, β-particles or electrons, and Gamma rays, or light emanations, on the one hand, and the other remaining portion into a new element called radium A, which only exists for a few minutes and hurries on through other changes till it finds a temporary rest in polonium (No. 84 in the Table of Atomic Numbers). Consequently, though constantly being formed by radium, very small quantities are usually found in existence in association with the mother-element, although apparently in radium salts the niton is sometimes held, "presumably in a state of solid solution" (J. N. Friend) but in this case, by heating, the gas can be driven out.

Niton, which freezes at —71° centigrade shows its greatest intensity of luminosity (that is the brilliant phosphorescence which expresses the energy liberated during its disintegration) in its solid or frozen state; but both as a liquid and as a gas it glows strongly. J. N. Friend tells us that "the colour emitted by the solid varies from steel-blue after melting point to orange red at lower temperatures." It is remarkable, he says, that when exposed to the action of niton, certain compounds such as carbon dioxide, ammonia, hydrochloric acid and water slowly decompose into their constituents, showing the continuous emission of energy from this gas, though exactly how it acts upon them does not seem clear.

The radiation of niton into the atmosphere from radio-active substances in the soil has been proved by the fact that if a negatively charged wire be exposed to the air it becomes radio-active through a deposit which can be removed chemically or by rubbing, and this deposit proves to be the emanations of thorium and radium, that is thorium emanation and niton. In general there is said to be more niton in the higher levels of the atmosphere.

It may perhaps be a source of wonder that there is any radium left at this stage of the world's history if it is gradually, though so slowly, breaking down into helium nuclei and niton. But radium itself is "descended," so to speak, from uranium by the disintegration of the latter into a series of products ending in radium. Uranium has an enormous lifetime, and it would take five thousand million years for half of a crystal the size of a pinhead to disintegrate.

CHAPTER X

HOW WE ARE BUILT

Synopsis of Contents: Value of the study of that from which we sprang. Search for the ultimate origin of all. Empty space and its properties. Pause before the Birth for which all is prepared. Life with its power of choice now to be born. The love of flowers explained by their faithfulness to the Trust of Life. Impressions and views of the principles of the building Life-Force. Satisfying and convincing nature of the revelation. (1) Importance of the individual; but always in combination. Sharing and "friendliness" with stretched out hands. (2) "Holism" or wholeness of the organism evolved by combination of individual electrons which are not fused in the process. Mystery of life involved in this principle. All further unfoldings of life apparently a further development of this principle. (3) Electrons and protons in the nucleus the essential "life" of the atom. Dispersing of these in radio-active substances resulting in disintegration of atom. Is this a foreshadowing of the "rule of two" in Nature. Views of ancient alchemists as to male and female in the inorganic. The question considered. Tearing asunder of protons and electrons in nucleus the doom of the atom. Suggestion of inviolate nature of duality at heart of the structure. (4) Interpolated numbers in the building of the atom. The pause in the building. Unfilled circles and the need for consolidation. Application to human experience. (5) The spiral form and rhythm in the building. Spirality and rhythm in all Nature. Rhythm in the order of elements, from simple perfection to more complex pattern in rhythmic waves. Does this exemplify our life rhythm? A comparison. (6) The "unenclosed" in the forefront of evolutionary movement. Exemplified in early animal and vegetable forms. Disclosed in the vital elements chosen to form the matrix in which life is cradled. The call of the Life-Force for the unwalled as pioneers of the evolutionary movement.

We are approaching the end of our short study of the building of the inorganic. The field to which we have confined ourselves has been a small and circumscribed one, and I am aware that there has been some repeti-

tion of detail, but as I am hoping that this book will be of use to some who have never had time, opportunity, or perhaps inclination to study these matters, I have been anxious to make the road as clear and easy as possible.

I have made no secret of my belief in the reason for such a study, even for people whose business in life seems to be very far from scientific theories or facts. I have no doubt whatever that we shall gain immensely by even a small genuine effort to understand that from which we sprang, and that it will make life clearer for us in a number of directions, more inspiring and less of an enigma. This is my own experience, even though I know that what one seems to have learned and gathered is probably not all ultimate truth and one may have to change one's views on many points. We used to be warned continually against the danger of thinking subjectively, but who can in reality do anything else? The true objectives are so hidden from us, and we can only approach them by symbols and inferences from symbols.

The men of science in the present day are making a superhuman effort to reach reality. "Our great knowledge," writes Professor Sullivan,[1] "has given us a sight of deeper difficulties and more irreconcilable facts, and yet the impression is strong that we are on the eve of some great illumination, as if the physics of the moment is in the darkness that precedes the dawn." It almost seems as if they were breaking through the last barrier to find . . . Nothingness. Thinner and thinner grows "matter" for the physicist. "Empty space" grows more and more immanent with the

[1] *The Basis of Modern Science.*

portent of a world in process of creation. Upon this, it seems, all eyes are fixed with a sort of expectancy. " The true nature of physical phenomena is to be sought in space and its properties," writes Sir Oliver Lodge ; and again : " Something in space it is which welds particles together by cohesion into a tangible body, and welds bodies together by gravitation into a cosmos ; so that the properties of that interstitial space are likely to form the greater part of the physics of the future." All seems to be ultimately a " modification of vacuous space. Perhaps life is a modification of space too."

Here we seem to come restfully at last to the foundation of all things ! " Dust thou art and unto dust shalt thou return," but the dust is not material but spiritual in its essence, for what can empty space be but pure Spirit ? And the only alternative to this is the view that we arrive by no means out of nothing whatever.

Finally empty space may vanish too—a symbol, merely, of the unknowable ! " Canst thou by searching find out God ? " Perhaps not, yet it might be possible to discover that there is nothing else !

So whilst all the scientific world is filled with a silent, almost passionate expectancy of some great revelation —some unification of all things in their " ethereality " —we, who have only tried to see how the Life-Force has built up that which it has brought into being, may feel the glow of their anticipation and see the world in a less dull and material light through these still nebulous glimpses into its origin. Looking at it in this light, and before coming to any principles which we may have gathered out of these studies in building, do we not find that many of the common things of life take on a new

meaning for us and intuitive things which puzzled us are explained ?

As we pause here in the hour before the great Birth for which we have watched the preparation, thoughts come, both solemn and sweet, and in this inspired moment the road is open. Whatever our creeds or beliefs, whatever our philosophy of life, here, surely, we can meet in quiet worship and reverence. All the Spiritual seems to hold its breath, for here is a crisis big with possibilities that hangs like a luminous cloud over the barren world. Only the Birth-giver hovers and broods over all.

Hitherto the Life-Force, whilst building with living bricks, fashioned out of living particles endowed with mysterious forces, has apparently guided the dance of those particles and formed and built up those bricks with a sure directive power. All the while channels have been preparing for something beyond blind obedience. Already there have been hints of a power of choice, of a difference in the individual behaviour of those particles, even under the direct guidance of the Life-Force. Already life has been dawning and there has been a faint gleam of purposiveness in the unborn. Now the great moment has arrived and the inorganic is to receive its birth into a life of its own. Not yet conscious life, but for all that life with a power to choose ; a power to follow the highest path or to turn to an easier way, a power to enclose itself in safety and comparative stagnation, or a power to open to all the influences that bear down upon it and to " live dangerously " in the forefront of things. How will Life bear itself ? How will it maintain the great trust committed to it ?

That is another story, and some of it is sad and some has beautiful rays of light woven into it. But when in the early springtime the tiny leaves, with their transparent colour answering somehow to the liquid bird notes of joy around them, dance in the breeze, and we see the clear yellow of the daffodils with their tender grey shadows, replying from the earth—or when the bluebells make lakes of blue in the tangled woodland, or the wild rose breathes out its unearthly sweetness, so elusive that it is gone before we have found an expression for it—then, at such times as these, we feel that we are in touch with life that has not failed in the trust committed to it; life that is in joyful correspondence with That which brought it into being.

Why do we love flowers so much? What is their strange attraction for us? From the merely material point of view it is not explicable. Are they not simply the coloured organs of the vegetable world, developed principally in response to the insect carriers of the pollen? Are we children that we are attracted merely by bright colours and passing shows?

In this great hour when thought has flown back to the origin of all life, a higher and truer vision is given to us of all that has arisen since that solemn moment. We know that all that we see stands for Life given, a trust committed. The subjective does but veil a far more inspiring and mysterious reality—the interaction of the Creative Spirit with creation. Here is all the beauty and colour and symmetry of the Life-Spirit taking form; here is the created giving itself back in a beauty that has more than it received, for its own faithfulness is therein expressed, and the trust of life is not betrayed. In the clustering primroses within their nests of green,

or in the myriad earth-stars of the wood anemone there is something of ethereal beauty that transcends all our physical æsthetic visions. The touch of their petals as we stoop our faces to them is like that of nothing else on earth, unless it be the cheek of a very little child. They have indeed something infinitely childlike in their essence—not yet fully conscious, yet alive, and living in the direct sunlight of the Creative Spirit, the perfect life which was begun in those days of the Inorganic. No wonder we love them. They speak to us of such possibilities of perfect beauty, of obedience in freedom and peace, of all that we unconsciously hanker after in this world, of a great Trust to which none has been quite faithful.

Let us look back over the way we have travelled in our studies of the Inorganic and try to form some conceptions as to that Life-Force whose building we have humbly endeavoured to follow. Let us seek to discover principles that may guide us (as belonging to our own origin) in our everyday life, and visions of the meaning and the trend of things which may encourage us and awaken a new hope. Everyone will see his own vision in such a survey, and mine will not be like yours, yet both will be bits of the truth and I can only give what I see.

The first thing that impresses me is the satisfying and convincing nature of the revelation which has come to us in the study of that building. Satisfying, because one's whole nature is satisfied with the character revealed in the work. I see order and symmetry and beauty all on a grander scale than imagination could ever have reached; there is restraint and even severity in the fragment of the picture which is all that we have been

able to see; the lines run with the purity and sure touch of the Master Hand, they satisfy and exalt our craving for the ideal and the perfect; and whilst filling us with reverence, they lift us with their upward rush and show us for a moment our true goal and the circling upward path that has no end. Satisfying, because we feel that before that Mind which has been opened to us but a hair's breadth, all human intelligence must stagger, and yet we cannot turn away; it holds all that we need. It is convincing, because we are convinced of the worshipfulness of That which gave us being.

One turns again from contemplation of the Builder to the work of the building, and at once a number of things strike us, shedding light upon our everyday life.

One sees the immense importance of the individual, yet never for his own sake, always in his effect on the combination to which he belongs. Not one ultra-microscopic electron can leave the atom of an element without being definitely missed. As long as it wanders through space alone and unattached it counts for little, its potential energy remains locked within itself. But let an electron belonging to an atom of an element leave its place, and immediately the whole community is affected. The balance of electrical forces is upset, an "unsatisfied" condition results, and there is no rest till by some means the balance can be restored, in which process the atom may have completely changed its character by some combination with the atom of another element.

If the electron comes from the nucleus, the case is in a different category and still more fundamental, for that loss can never be made good, and once for all the

atom has changed its essential character and is an atom of a different element.

In the former case, which concerns the outer electrons of the atom, each unit may be regarded as a normal means of interaction between individual atoms. Nothing is clearer in all the story of building than the fact that except in the case of the inert gases, and this exception is more apparent than real, not even an atom must rest contented with its own completeness; it has a duty of further combination and co-operation. There is a very wonderful spirit of friendliness (if one may put it so) in the way these combinations are made. Atom calls to atom and group to group; there is a remarkable impulse to *share* electrons for the fuller completion and stability of the organised molecule. It is a world of stretched-out hands, and the gain is never for the individual—always for a larger issue, a higher building, fuller life in the group, greater stability. The individual counts largely; none can be disregarded, not one is unimportant, yet the individual only finds his worth in his relation to others; and all combination is for completeness and stability. *That is how we are built.*

In all such combinations something is evolved which did not exist in the electrons or protons which combined to form the atom or molecule. Yet the electrons and protons are not "fused," in the combination, as is clearly proved by the fact that radio-active substances emit the helium atoms and also electrons of which they are built, *unaltered* (α-rays and β-rays); also that single hydrogen nuclei or protons have been driven forth from nitrogen atoms by bombarding their nuclei with α-particles. Yet the atoms of radium and nitrogen

have quite distinct characters, chemical properties and affinities which, were certainly not in the electrons and protons of which they are built. What is this elusive something which from the very earliest combination—say that of the hydrogen atom with its one proton and one electron—has come silently into being without apparent cause ?

General Smuts in his most interesting book *Holism and Evolution*, describes it by the name of " holism " or wholeness of the organism in distinction from the parts of which it is composed, and undoubtedly it must result from some interaction or influence of part on part, yet it remains a deep mystery, for how is it that the combination of 10 single protons with 10 answering electrons and 10 married protons with their electrons living in the nucleus, can produce the atom of the inert gas neon, whilst 11 single protons with 11 answering electrons, and 12 married protons and electrons in the nucleus, result in the atom of sodium with entirely different characteristics, chemical properties and affinities ? Whatever *life* may be, surely here, at the very threshold of the inorganic is the first hint of it, and its source must lie in an inherent property, dependent upon combination, existing in the simplest expression of Creative Energy.

If we can grasp and accept this, no other higher manifestation of life need dismay us or seem " out of the picture," whether it be the unconscious life of the vegetable, the conscious life of the animal, the self-conscious life of Man or the spiritual life of his soul. All may be seen as the unfolding or emergence of this first principle whereby the combining units are inspired with that which individually was not apparent, and a

wholeness of being with something entirely new and mysterious, not to be explained by its component parts, arises.[1]

However this may be, the principle is clear and is well recognised : the whole is more than the parts. But further : the parts are not lost or fused in the whole, though sharing in its wholeness.

In the second case mentioned above—that of the electron which leaves the nucleus—there is no question of normal inter-traffic between atoms, and the issue is a vital one and goes to the heart of the community. Though all protons and electrons appear individually to be alike and equal, yet it is evident that from the beginning of their combination, their work and effectual value differs according to the position assumed. The nucleus is the central stronghold of the atom ; upon it the " holism " of the group of protons and electrons depends. Anything which touches this, threatens the whole structure.

Very little is known at present of the conditions prevailing in the nucleus, or of the action and inter-action of those closely packed protons and electrons which compose it. Are they in a state of quiescence, or are they spinning rapidly in their minute chamber ?

[1] " With the point of actual emergence of that which is currently distinguished as ' life ' we are not greatly concerned because we believe it will never be found. The universal process, as we see and imagine it, is strictly continuous ; and just as it is impossible to determine at what point ' consciousness ' emerges, so it is impossible to indicate the point of emergence of ' life ' in the familiar sense. There is no distinguishable dividing line between the living and the non-living. The emergence of biological life presents no more of a problem than the emergence of consciousness. The ' life in the broadest sense ' of Goethe, under which we include all phenomena is pre-biological, biological and metabiological, and these phases are strictly continuous." *God*, by J. Middleton Murry.

In the latter case one may suppose that magnetic forces are being gendered which may bind the electrons to peaceful pairing and quiet their antagonisms. But all this is speculation. Nothing seems to be definitely known as yet. All that we can say is that here (whether bound together in the form of helium nuclei, or separate as hydrogen nuclei and free electrons) a certain number of " married " protons and their partners dwell, as well as a definite number of single protons, reacting with electrons circling outside the nucleus. What the secret work of these " married " protons and electrons may be, appears to be unknown. They must in some way hold the essential " life " of the atom, for anything which breaks up the nucleus and scatters these, brings about the eventual dissolution of the atom.

In all cases of radio-activity, β-particles, which are electrons, are given off at some point in the series of changes, and these electrons *must* be " married " ones because there are no unmarried electrons in the nucleus. Therefore disintegration of the nucleus in radio-activity definitely involves the breaking up of the union of protons and electrons in the nucleus.

Is there in this secret partnership of protons with electrons in the heart of the community some dim foreshadowing of the " rule of two " which eventually shall entrust to two individual entities of " opposite sign " the future life of the community ?

The ancient alchemists, though utterly ignorant, of course, of the existence of protons and electrons, seem to be feeling in their dim prophetic way for something of the kind, and their writings are full of crude imaginings on the subject. In a chapter, for example, on Arabian and Syriac Alchemy, speaking of the *Book of*

El Habib, A. E. Waite says: "El Habib opens by affirming that all creation is constituted of agent and patient, otherwise male and female." The same thought seems to appear in the writings of the Arabian Geber who describes that unity which they conceived to be at the root of all things as "comparable to the microcosm, to Man and analogous beings" in that it was "male and female and therefore capable of marriage." And still more definite and strange is the belief in the "seed" of minerals, which the writer of *The New Light of Alchemy* describes as "a seed of all metals, generic to the whole group including mercury . . . known only to the sages," which seed he believes to be produced by the marriage of "the living male with the living female," which "project a germ for the procreation of fruit according to their kind."

We are looking for principles and not for mere analogies, and in the nucleus of the atom we cannot definitely say that we are catching a first glimpse of that "rule of two" which plays so large a part in living organisms. But certain facts are noticeable. We observe that the "married protons" and their partners —*taken together*—do not affect the nuclear charge which is what causes an atom to be an atom of a particular element; they simply affect the *weight* of the atom which does not alter its individuality. Thus lead which is developed from disintegrating radium has fewer married protons than ordinary lead, and is consequently lighter, yet it is *lead*, and not any other element.

Hydrogen is exceptional in that it has *no* "married protons," yet its single proton has individuality and is a hydrogen atom and nothing else, and even if it lose its attendant electron that single proton is still hydro-

gen, though now ionised, or having an atomic charge, and calling for an electron. But in general the life of the atom depends upon these pairs in the nucleus, and anything which separates them breaks up the whole atomic structure. When a β-particle is shot forth by radio-activity from an atom, that atom, as we have seen, is no longer the atom of the radio-active element which ejected it. When a proton is forcibly driven out from the nucleus of a nitrogen atom by bombardment with α-rays the nitrogen atom ceases at once to be nitrogen. In the case of an α-particle the two married pairs which are contained in that firmly welded body are not torn asunder, and their leaving the atom *together* might not have seriously affected it ; but they carry with them, inevitably, two other single protons whose loss affects the nuclear charge and at once alters the character of the atom. Apparently therefore the facts are that no proton or electron belonging to the nucleus can leave it *separately* without causing the disintegration of the atom. Their departure is its doom. The lost particles can never be replaced, stability is gone for ever, and sooner or later the whole of that element will have broken down into a less highly organised condition, having lost for ever the characteristics that made it what it was before its disruption.

How far it is legitimate to accept this as a principle of building and to apply it in the far later work of the Life-Force I do not know. A true, deep-seated principle may be applicable both in the individual life of the higher organism (since through embryology we have learnt that the individual very usually repasses in brief through the way by which it has evolved) and in the further process of the natural groupings of the individ-

ual. Is it possible that this principle of the inviolate nature of the duality at the heart of the structure can be applied to the family, the nation, the race of mankind? Is this how we are built?

Passing from the case of the completed atoms and their electrons, and going back over the way in which these atoms of the several elements have been gradually built up, one is arrested by that strange case of the so-called "interpolated numbers" which we studied. We remember the sudden, and apparently unaccountable pause in the building, and the upheavals and unusual characteristics in the elements which came into being at this juncture. Eventually all was accounted for by the fact that in the exigencies of the forward movement certain circles in the inner being of the structure had been left unfilled, and that the building could not proceed till this was made good.

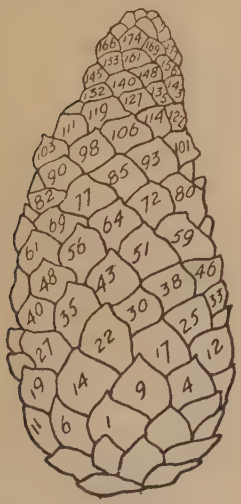
We must remember that all this building of the elements is entirely prehistoric and is a period of evolution carried on, one must suppose, before the world was. Its building, which we can follow in its long-completed form, should give us true analogies for the present building of the same Life-Force: the principles presumably are the same, whether a series of elements are being evolved, or a single human organism developed to its completeness.

Do we here get a hint of the ultimate cause of many quite well-known happenings in the course of our own physical, mental and spiritual development? The sudden check that so often brings an ardent young mind almost to a full stop, and temporarily clouds all the brilliance of its career, is too well known to need description, and I think the cause is generally seen to be an

over-development of the mental at the expense of the physical, and the pause to be due to the necessity for consolidation. But later in life, I think there still may come these blank places. Often they are unknown to any but the individual who suffers them. Wherever there has been a vigorous growth, whether in the spiritual, the mental or the physical, it appears that there is a tendency to leave gaps in the circles of our being which *must be filled* before we can proceed healthily. Perhaps if we understood this better we should be less dismayed at such happenings, and should even see how to guard ourselves and others from them to some extent. Here again it may be really helpful to see how we are built.

To turn to another point. During our study of the progression of the elements arranged according to their atomic numbers, we have become aware of the spiral form and of the rhythm of the building. If we had only known the elements as we chance to meet them in Nature, without order or arrangement, we could never have discovered this hidden spirality and rhythm. It is owing to man's patient work in weighing and examining and setting the elements in their true order that this principle has been uncovered. It is especially interesting and helpful to discover it here, because in later developments it is so evident, though often its innermost manifestations are hidden from the careless glance. We see it written large in the spiral nebulæ in the heavens, we trace it in the movements of the planets and of our own earth around the sun, revolving as we go ; the cosmos is indeed a vast display of spirals and rhythms whose meaning is all unknown, for Man has not the master-key which shall unlock the mystery of

the central spiral gathering all into one. Down here, on this earth, in the later developments of the work of the Life-Force, the humble little fircone whispers to us of that great central spiral, and teaches us by its own hidden winding thread, invisible to sight, beneath the secondary spirals which spring to our view, but easily demonstrable by a manner of numbering the scales,



Numbered Fircone.

When the Fircone has been numbered by certain rules, it is possible to follow the course of the central spiral by turning the cone in the hand and reading the numbers 1, 2, 3, etc., as they come into view.

that there is an inner core to things, a spirality and a rhythm which take in all and leave no fact outstanding, but carry all up in its magnificent sweep to the great unknown end.

And here in the earliest building of the Life-Force on our earth, the same principle comes to view uncovered by man's patient investigation and search after the truth.

Is there anything in all creation that does not show rhythm in some form ? It may be rhythm of recurring number as with the placing of the leaves on the trees, it may be rhythm of movement as with the alternate expansion and contraction of the muscles of the heart and of the lungs, or the movement of the leaflets of the " telegraph plant " ; it may be rhythm of unfolding and re-folding, as displayed by plant life through the seasons of the year ; it may be the rhythm of spinning worlds, or of vast orbits whose period of recurrence is never twice in a human lifetime. Yet in every rhythm, vast or minute, there is an underlying principle of " becoming," and between every rhythmic heart-beat we are making an infinitesimal movement on the spiral path. Nothing stands still, it is a spiral and not a circle in which we are involved, and it must have a goal.

Can it be of no significance, this recurrence of the spiral throughout the work of the Life-Force in every department ? To nearly everyone who seeks a path through the labyrinth of the natural world the spiral presents itself sooner or later ; to those who seek a door to the spiritual, this clue almost inevitably attracts and invites them from innumerable points.

As a medical friend has pointed out to me, we come into the world with a spiral movement ; the mechanism of our birth sets us already in that first moment of life's journey on this winding path that has no end. Another friend, to whom I am indebted for some very interesting examples of the spiral (which has become for her the clue to be followed in faith and hope), gives me the following very fascinating account of the spiral coiling of the chick in its egg which she illustrates with a clever drawing. " It is instructive," she says, " to notice the

spiral way in which a chick is coiled in its shell; a mason wasp is packed just in the same way into its mud nest. In both instances the earlier stage of life develops to a certain point, but at last a moment comes when it must break through the enclosing circle or ellipse, and *make its spiral larger*. Then comes freedom; the creature stretches and unfolds, and a new and glorious, hitherto unguessed at, condition of life is entered upon. Like a watch whose spiral spring has been set free, it begins to 'go.'"

In a later letter in answer to some remarks and questions of mine on this subject she says: "the chick is, as you say, coiled like an ammonite" (fossil). "The head and body are attached to and round the yolk, which feeds the chick through the fundament and is not wholly absorbed till the moment of hatching, or a little before. The legs and wings are also wrapped round the yolk bag." She goes on to refer to "the spiral string at each end" of the egg, and refers me to Sir Theodore Cook's *Curves of Life*, where I find the following passage: "The rotation of a bird's egg while descending the oviduct gives a spiral twist to the envelope as it turns in its progress, and thus the little stringy portion of 'white' at each end is strengthened by the spiral formation imparted to it and suspends the egg within the shell. Much the same rotatory process occurs during the birth of mammals." So it is not only human beings who enter life by the spiral path.

Referring to Sir Oliver Lodge's book, *Life and Matter*, this same friend points me to the following very pregnant note amongst the "Definitions and Explanations" attached to some of his matter. "*Spire of Destiny*. The phrase used in the concluding paragraph

of this book signifies that the progress of the universe may be represented as a spiral. Superficially, the changes recorded in history seem to recur in cycles, and to a certain extent the cyclical or circular change is real; but the apparent circle is *never a closed curve.* No period is an exact repetition of another. All must be spires or turns of some great and progressive spiral—a spiral being the combination of circular with progressive motion; and faith suggests that the spiral of destiny is upward-tending." Here is the "clue" followed as far as one may go in this earthly life, and another correspondent points out that not to individuals merely but to nations and peoples has such a revelation been granted. "In the Egyptian Mysteries," he says—"and through them in Free Masonry—is manifested the great spiral staircase to the Great Architect."

In any account of the building of the Life-Force it is clear indeed that the spiral must be taken into account.

As the Life-Force builds up the elements one by one, the rhythm of the building becomes manifest. From the simple perfection of helium to the more complex perfection of neon, the wave swells to its height at carbon, and declines to its rest with the passing from fluorine to neon. And again another wave is born, and swells, and falls to rest in argon in a higher perfection, and hence it passes in rhythmic wave to yet more complex patterns of perfection. How if this exemplifies our life-rhythm? From the simple perfection of the nature created and trusted to us by the Life-Force, on through the increasing urge to the higher and more complex perfection which is our goal at this stage, till we sink to peace, our journey done. This, at least, is

how it should have been if we had been faithful. Now is the rhythm sadly broken, and only a few seek the perfection of the pattern which is given to them to complete. Yet is the Life-Force undefeated; the great wave of Becoming cannot be stayed; a new and larger Way is opened, and once more a choice is offered to man.

In early youth there is the natural desire to rest in the simple perfection of the early happiness. As the elements at the beginning of the period seek to return to the perfect pattern they have left behind them, so the young soul looks back to the careless freedom and joy of its beginning. In middle life it can no longer doubt that it has a work to do. It stands at the balance. Will it frantically clutch once more at the past, throwing away all its gains, or will it patiently look on, endeavouring to fulfil the rhythm of its being and to attain the new perfection which is its rest? To true souls who have received the new birth from the breathing of the Life-Force there comes the approach to the final peace with a sense of fulness and completeness of life. The rhythm is rounded and softly dies into the perfect pattern.

One last principle springs to view as we pursue the rhythmic spiral of the building of the Life-Force. It is an outstanding fact in the history of biological evolution that it is the *unenclosed* which are in the forefront of that movement. This is clear in the distinction between the early microscopic forms of animal and vegetable life, the cell of the latter enclosed within a wall of cellulose, whilst that of the former is open to every influence of its environment. It may be safe and peaceful to shut the doors; to "live dangerously" is, however, the only way on!

It is almost startling to discover the same principle far down in these depths of the inorganic. Those elements, as we have seen, which are eventually to build the body of living things, are the unenclosed ones of the early periods, with a small nucleus and few surrounding " shells " of electrons.

Apparently if we would take a place at the point of the pencil which is writing the great story of evolution, we must be found amongst the unwalled. Neither class nor caste, nation or race, may enclose us, neither prejudice nor tradition may fence us round ; only the breathing of the Life-Force may surround us, and the laws of the spiritual compass us about. If we are open to this influence the Life-Force will use us and we shall serve a purpose. Can we ask more ?

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PRINTED IN GREAT BRITAIN BY
MACKAYS LIMITED, CHATHAM